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MAXDOSE-EPA: A Computerized Method for Estimating Individual Doses From a High-Level Radioactive Waste Repository

Office of Radiation Programs
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May 81

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Barry L. Serini, and Bruce Smith.

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As presently written, the output includes a listing of the input data, a table of calculated doses, and a table indicating contaminated areas in square meters. The dose table lists, for each time and distance, the dose rate in rem/y, the nuclide making the largest contribution to the dose, and its percentage of the total dose. The code is written in FORTRAN, requires less than 200 K storage, and runs in less than 30 seconds. The code calculates the maximum dose and makes many conservative assumptions that shorten the run time to under 30 seconds.

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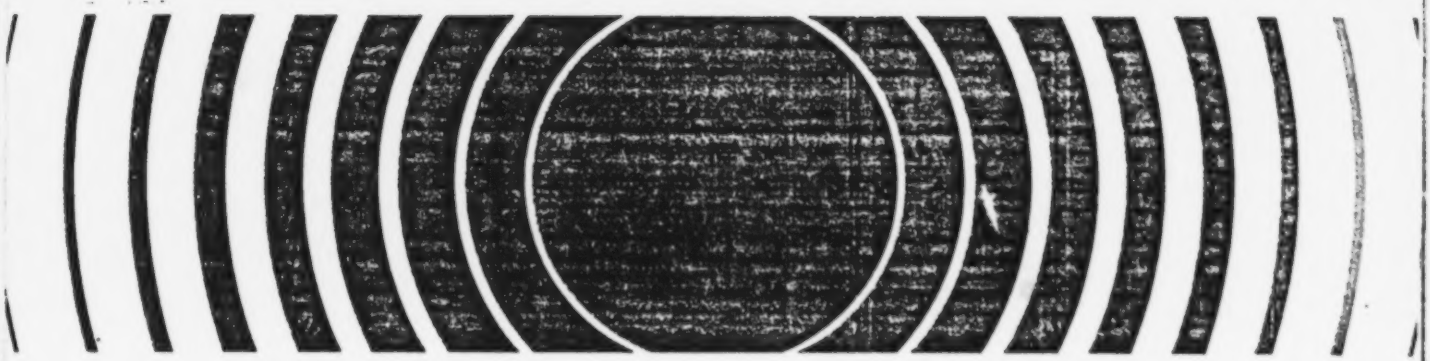

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MAXDOSE-EPA: A COMPUTERIZED METHOD FOR ESTIMATING INDIVIDUAL DOSES FROM A HIGH-LEVEL RADIOACTIVE WASTE REPOSITORY

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Washington, D.C. 20460

ABSTRACT

The MAXDOSE-EPA computer code is a methodology developed by the Office of Radiation Programs to estimate the potential radiation doses from accidental releases of radionuclides from a repository for high-level radioactive wastes sited in deep geologic media. The code is intended to be applicable to a generic repository. The model parameters describing the characteristics of the repository and its environment can be varied to show the effects of different characteristics. This report describes the equations used to obtain the radionuclide concentrations in the environment and to calculate radiation doses to man via inhalation of air and ingestion of water, milk, crops, beef and fish. A listing of the code, an input guide, and a sample problem are included.

Accidental or unexpected events at a geologic repository can release radioactivity into the air above the repository site or into the aquifer overlying the geologic media. A modified Gaussian plume equation from AIRDOS-EPA was adapted for our use for the air pathway. Releases into the aquifer are assumed to be dispersed in the aquifer in the horizontal direction only because we assume material is released uniformly through the aquifer thickness. The code can estimate the dispersion of up to 20 nuclides. Radionuclide concentrations in meat, milk, fish, and fresh produce are obtained by coupling the air or aquifer concentrations with terrestrial food chain data. Dose conversion factors are used to convert radionuclide concentrations to individual dose equivalent commitment rates.

A sample problem illustrates use of the dose factors and the computer code to calculate maximum doses to individuals. For ingestion pathways, doses are calculated for any two organs. These are determined by the dose conversion factors. Inhalation doses are also calculated for two organs, to be specified by the user.

As presently written, the output includes a listing of the input data, a table of calculated doses, and a table indicating contaminated areas in square meters. The dose table lists, for each time and distance, the dose rate in rem/y, the nuclide making the largest contribution to the dose, and its percentage of the total dose. The code is written in FORTRAN, requires less than 200 K storage, and runs in less than 30 seconds. The code calculates the maximum dose and makes many conservative assumptions that shorten the run time to under 30 seconds.

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1. Introduction

The MAXDOSE-EPA computer code is a methodology developed by the Office of Radiation Programs to estimate the potential radiation doses from accidental releases of radionuclides from a repository for high-level radioactive wastes sited in deep geologic media. The code is intended to be applicable to a generic repository. The model parameters describing the characteristics of the repository and its environment can be varied to show the effects of different characteristics. This report describes the equations used to obtain the radionuclide concentrations in the environment and to calculate radiation doses to man via inhalation of air and ingestion of water, milk, crops, beef and fish. A listing of the code, an input guide, and a sample problem are included.

The repository is sited deep below the surface and is placed in either salt or nonsalt (granite, shale, basalt). It is filled with high-level waste packaged in canisters. In a salt repository the canisters disintegrate in 100 years; in nonsalt, 500 years. The bedded salt, shale, and basalt repositories have overlying and underlying aquifers; the granite repository has only an overlying aquifer; the dome salt has an overlying aquifer and an aquifer around the dome (EPA79b). The events causing releases are drilling and fault movements. Releases can occur by penetration (drilling) into waste or from water in a region of contaminated backfill, "the tank" (EPA 79d). Both drilling and faulting events either hit the waste directly or hit a contaminated repository region where nuclides have leached after canisters have failed.

It is assumed that radionuclides from the waste repository are released to the aquifer overlying the repository, directly to the land surface above the repository, or directly to surface water such as a lake or river. Releases to land surfaces and ground waters are the most important routes by which individual doses may be incurred.

A modified Gaussian plume equation from AIRDOS-EPA (EPA79a) was adapted for our use for the air pathway. Releases into the aquifer are assumed to be dispersed in the aquifer in the horizontal direction only because we assume material is released uniformly through the aquifer thickness.

Radionuclide concentrations in meat, milk, fish, and fresh produce are obtained by coupling the air or aquifer concentrations with

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terrestrial food chain data. Dose conversion factors are used to convert radionuclide concentrations to maximum individual doses.

The code can handle 8 types of events which can cause unexpected releases, up to 13 time periods, up to 10 locations from the release site, and the dispersion of up to 20 radionuclides. The user has the option of changing any of the input data (except the radionuclide data) to check the response of input data changes. For example, the user can test option of waste containers failing immediately.

The code will do one release case per run. After calculating the concentration of the isotopes, each concentration of a radionuclide is multiplied by the appropriate ingestion rate and dose conversion factor. This gives us a 5-dimensional dose array: a) the nuclide, b) the time, c) the distance, d) the pathway, and e) the organ exposed to the radionuclide. The nuclide contributing the highest dose, and its percentage, are calculated and displayed. For drilling events which release radioactive materials to the aquifers or to the land surface, the areas contaminated above preselected dose levels are calculated.

As presently written, the output includes a listing of the input data, a table of calculated doses, and a table indicating contaminated areas in square meters. The dose table lists, for each time and distance, the dose rate in rem/y, the nuclide making the largest contribution to the dose, and its percentage of the total dose. The code is written in FORTRAN requires less than 200 K storage, and runs in less than 30 seconds. The code calculates the maximum dose and makes many conservative assumptions that shortens the run time to under 30 seconds.

Section II of this report discusses the types of accidental releases that can occur at a high-level repository. In Section III the equations used to estimate the environmental concentrations from the different types of releases are presented. Section IV discusses input data required to use the code.

Appendix A includes a listing of the code; Appendix B includes a sample input and a sample problem. The code can estimate the dispersion of up to 20 nuclides. A sample problem illustrates use of the dose factors and the computer code to calculate maximum doses to individuals. For ingestion pathways, doses are calculated for the bone marrow and the organ receiving the highest dose from a given radionuclide. For inhalation pathways, the organs considered are the lungs and the organ receiving the highest dose.

II. Release Mechanisms

The extent to which geologic media can serve as barriers to radionuclide migration depends principally on the geologic properties of the media and the possibility of catastrophic geologic events. The ideal site for a high-level repository would be geologically stable and isolated from aquifers and from the biosphere. However, an ideal site does not exist; the code covers a selected range of possible circumstances for transport of radionuclides away from the repository site once the primary containment system has been breached (EPA 79b).

Most releases of radionuclides would occur from unintentional or unplanned events, either natural or produced by people (e.g., faulting movement; drilling for mineral resources)(Go81).

Release to An Aquifer

The release to an aquifer results from a permeable pathway being created in the rock between the repository and the aquifer. This pathway may be created by a new faulting event, movement of an old faulting event, or more likely, by a deep drilling event which penetrates through the aquifer and the repository. The hole created by a deep drilling through the aquifer is generally sealed; however, the seal may degrade, leaving a small permeable pathway which connects the aquifer to the repository. Radionuclides dissolved in water are transported from the repository to the aquifer where it is assumed they are dispersed horizontally by diffusion and aquifer flow. It is then assumed that individuals drill a well into the aquifer and use the water for residential use. The code calculates the maximum dose to individuals using the water.

For EPA's dose assessment, if the radionuclides are inhaled (via resuspension into the air) doses were calculated for lungs and the organ receiving the highest dose. If radioactive materials were ingested, doses were calculated for bone marrow and the organ receiving the highest dose. However, the user may calculate any organ dose by changing intake rates and dose conversion factors.

Release to Surface Water

The release to surface water results from the assumption that artesian conditions exist and a drilling or faulting event opens a pathway to surface waters (although such a site would not be a likely candidate for a repository) (EPA 79b). The pressure in the repository is enough to force contamined water to the surface lake or river.

Release to Land Surface

Two situations are considered where radioactive materials are released from the repository to the land surface. In the first case the drill hits a canister and carries a fraction of the contents to the land surface where it is deposited. In the second case the drill penetrates the repository backfill (the tank) containing contaminated groundwater. In a salt repository some of the backfill is ejected to the surface from the great pressure in the tank. The pressure is from: a) weight of the overburden, and b) decay heat causing expansion in gases. The backfill in the nonsalt repository is transported by the drill to the surface.

After the nuclides are deposited on the land surface the air concentration is calculated using equations from AIRDOS-EPA. The doses received are a function of the concentration, breathing rate, and the dose conversion factor. In the case of a direct hit to a canister, the nuclides are transported to the surface in an insoluble form (Class y-ICRP No. 2), while in the tank release they are in a soluble form (Class w-ICRP No. 2). The appropriate dose conversion factors must be used for the soluble and insoluble forms of each nuclide.

III. Description of Functions of MAXDOSE-EPA

MAXDOSE-EPA is organized by functions and subroutines to calculate radionuclide concentrations in the environment for the following types of events and releases. For a more complete discussion of the equations, see Golden's report (Gold).

A. Drilling Release to the Land Surface from a Direct Hit of the Waste (Function AIR, Km)

In this situation a drilling event into the repository results in a fraction of waste being transported to the land surface. The radioactivity deposited on the surface is resuspended and dispersed in the air. The wastes are assumed to disperse radially from the point source. As they spread they are removed by decay and infiltration into the soil. The dose is calculated primarily for the lungs from inhaling the contaminated air from the drilling event. The air concentration near the drilling site is described by the following equation. The dispersion and deposition rate are modelled after AIRDOS-EPA.

$$\text{Concentration} = \begin{matrix}\text{source term} \\ \text{at } t_{event}\ (t_e)\end{matrix} \times \begin{matrix}\text{atmospheric} \\ \text{dispersion}\end{matrix} \times \begin{matrix}\text{deposition} \\ \text{to ground}\end{matrix} \times \begin{matrix}\text{radiological and} \\ \text{environmental depletion}\end{matrix}$$

$$C(X,t) = fQ_0 e^{-\lambda_d t_e} (2.3E\text{-}17)\left(\frac{X}{1000}\right)^{-1.43} e^{-\left(\frac{X}{2595}\right)^{.37}} e^{-t_g(\lambda_d+\lambda_s+\lambda_{rs})} \quad (1)$$

where

$C(X,t)$ = the concentration in the air (Ci/m^3)
f = fraction of repository released to land surface
Q_0 = inventory of isotope at repository sealing (Ci)
λ_d = radiological decay constant (y^{-1})
t_e = the event time (y)
X = the distance from the borehole (m)
t_g = the time after the event occurs (y)
λ_s = the soil removal term (y^{-1})
λ_{rs} = the resuspension term from soil to air (y^{-1})

8. Drilling Release to an Aquifer as a Result of Direct Hit of the Waste (Function DRILLm, K=2)

In this event, a canister is directly hit and the fraction of the canister remaining in the repository releases radionuclides to an overlying aquifer. There are two methods of calculation: one for leach-limited isotopes, the other for solubility-limited isotopes. The basic form of the equations are:

Concentration = (unit step function) x (dispersion and diffusion) x (source term)

The unit step function is the same for both releases. It models the distance the nuclide has moved downstream in the aquifer.

$$U(T_g - KX/v) = \begin{cases} 1 \text{ if } T_g > KX/v \\ 0 \text{ if } T_g < KX/v \end{cases} \quad (2)$$

The dispersion and diffusion are also the same for both equations, i.e.,

$$\frac{1.0}{8\pi\sqrt{(4\pi DvX)}}$$

For the leach-limited source term, the equation is:

$$Q_1'(t) = f\lambda_1 Q_0 e^{-\lambda_d(t_e+t_g)} e^{-\lambda_1(t_e)} \quad (3)$$

Thus, the leach-limited expression becomes:

$$C_i(X,t) = \frac{U(t_d - KX/v)\, Q_i'(t)}{B\epsilon\sqrt{4\pi DvX}} \qquad (4)$$

For the solubility-limited case, the source term is the (flow rate of the aquifer) x (solubility).

The solubility-limited source term equation is:

$$Q_s'(X,t) = [K1 + K'(t_d - KX/v)]\left[CVAe^{-\alpha(t_e+t_d-KX/v)} + CVBe^{-\beta(t_e+t_d-KX/v)} + CVC\right] AS_i \qquad (5)$$

Thus, the solubility-limited expression is:

$Q_s'(X,t)$ x (decay in aquifer) x (diffusion and dispersion)

$$C_s(X,t) = \frac{U(t_d - KX/v)\, Q_s'(X,t)\; e^{-\lambda_d KX/v}}{B\epsilon\sqrt{4\pi DvX}} \qquad (6)$$

where

λ_i = leach rate (y^{-1})
A = cross-sectional area of the aquifer perpendicular to the flow (m^2)
K1 = the initial permeability (m/y)
K' = the rate of change of the permiability (m/y^2)
S_i = solubility of the i^{th} nuclide (Ci/m^3)
CVA, CVB, CVC, α, β = constants modelling the changing hydrologic gradient
B = the aquifer thickness (m)
ϵ = the porosity (the ratio of the volume occupied by pores to the total volume of a geologic material)
v = the interstitial velocity of groundwater flow in aquifer (m/y)
D = the diffusion constant (m^2/y)
X = the distance away from the drill hole (m)
K = the retardation factor
Q'(t) = source term (Ci/y)

C. Release to Aquifer from a Faulting Event which Destroys a Line of Canisters (Function FLTH, K=3)

This function (K=3) calculates the concentration of radionuclides in the aquifer from a fault movement which destroys a number of canisters. If the radionuclide is leach limited, the equation for concentration is:

$$C_i(X,t) = \frac{f\lambda_1 Q_o e^{-\lambda_d(t_e+t_d)} e^{-\lambda_1 t_d}}{\epsilon B L \sqrt{4\pi D v}} \int_{1.0}^{Kt_d/v} \frac{e^{-\lambda_1(Ks/v)}}{\sqrt{s}}\, ds \qquad (7)$$

If $Kt_d/v > X$, then X is the upper bound on the integral.

$F_a = vWc\beta$

This represents an aquifer-limited flow rate. It is a conservative assumption, assuming the entire aquifer can flow through the path of the fault. $F_a S_i$ yields the total number of curies per year dissolving into the aquifer. The nuclides are spread over the effective cross-sectional area of the aquifer, i.e., ϵBL. Dispersion and diffusion are the same as in equation 7. The nuclides decay in the aquifer as they travel. For a solubility-limited radionuclide, the equation becomes:

$$C_s(X,t) = \frac{F_a \; S_i}{\epsilon BL \sqrt{4\pi D v}} \int_{1.0}^{Kt_d/v} \frac{e^{-\lambda_d(Ks/v)}}{\sqrt{s}}\, ds \qquad (8)$$

where

L = the length of the repository, parallel to the flow of the aquifer
W = the width of the repository perpendicular to the aquifer
S = a variable used to evaluate the integral, representing the distance
F_a = aquifer-limited flow rate (m^3/y)

The upper bound of the integral indicates the distance the nuclide has traveled. The source term is a line source in this case, as opposed to a point source in the previous cases. The integral is evaluated in MAXDOSE-EPA using a routine called DCADRE(IMSL).

D. Release to Surface Water from a Drilling or Faulting Event (Function STREAM, K=4)

In this case there is no dependence of dose versus distance because of the velocity at which rivers flow and the small distances the radionuclides travel. Thus, nuclides do not have time for significant radioactive decay. The radionuclide concentrations in the water are expressed by the following equation:

$$C(t) = \frac{\lambda_1 Q_o f e^{-\lambda_d t_e} e^{-(\lambda_d+\lambda_1)t_d}}{F_s} \qquad (9)$$

where

F_s = volumetric flow rate of surface stream (m^3/y)

There is no release to the aquifers in this case, and the dose pathways are above-ground food sources.

E. Release to Land Surface Resulting from a Drilling Event which Disturbs the Repository (Function DRNHLS, K=5)

This release is similiar to the first (K=1) except for the radionuclide source term. The source term is a volume of contaminated repository water. In the case of a salt repository, the radioactive wastes leach into a common volume, referred to as a brine pocket. For a granite repository, a volume of contaminated backfill (the tank) is transported to the land surface by a drilling event. The equation for calculating the concentration of a radionuclide in the air above the drilling event is described below.

Concentration = (source term)x(atmospheric dispersion)x(deposition to ground) x(radiological and environmental depletion)

The above equation has a leach-limited source term of:

$$Q_l'(t) = fQ_o\left[1-e^{-\lambda_1(t_e-c1)}\right] e^{-\lambda_d t_e}\left(V_d/V_t\right) \qquad (10)$$

and a solubility-limited source term of:

$$Q_s'(t) = S_i V_t \qquad (11)$$

Thus, for a leach-limited radionuclide

$$c_l(X,t)=fQ_o\left[1-e^{-\lambda_l(t_e-cl)}\right]e^{-\lambda_d t_e}(2.5E\text{-}17)\ \left(\frac{X}{1000}\right)^{-1.43} \tag{12}$$

$$e^{\left(-\left(\frac{X}{9595}\right)^{.57}\right)}\ e^{\left(-(\lambda_d+\lambda_s+\lambda_{rs})\ t_d\right)}\left(V_d/V_t\right)$$

The solubility-limited expression is:

$$c_s(X,t)= S_i V_d\ (2.5E\text{-}17)\quad \left(\frac{X}{1000}\right)^{-1.43}\quad e^{\left(-\left(\frac{X}{9595}\right)^{.57}\right)} \tag{13}$$

$$e^{\left(-(\lambda_d+\lambda_s+\ \lambda_{rs})t_d\right)}$$

Where

cl = canister life (y)
V_t = volume of tank in the repository
V_d = volume of waste carried on the drill

F. Release to an Aquifer from a Drilling Event which Disturbs the Repository (Function DRNHAQ, K=6)

This release (K=6) is subdivided into two parts--for a salt and a nonsalt repository. For both repositories the flow through the borehole is modelled as:

F_a = (area) x (permeability) x (gradient)

$$F_a = A(K1+K'(t_d-KX/v))\left[CVAe^{-\alpha(t_d+t_e-KX/v)}\right. \tag{14}$$

$$\left.+CVBe^{-\beta(t_d+t_e-KX/v)}+CVC\right]$$

For the leach-limited granite release:

$$c_1(X,t) = F_a \frac{fQ_0 e^{-\lambda_d(t_e+t_d)} \left[1-e^{\lambda_1(cl+KX/v-t_e-t_d)}\right]}{V \varepsilon \delta \sqrt{4\pi DV}} \tag{15}$$

For the solubility-limited granite release:

$$c_s(X,t) = \frac{F_a S_1 e^{-\lambda_d KX/v}}{\varepsilon \delta \sqrt{4\pi DV}} \tag{16}$$

The salt repository is more complex in its mathematics. The differential equation used to solve the granite case no longer has a closed analytic solution due to significant alterations. First a differential equation describing the buildup in the tank prior to release is developed with boundary conditions. The tank is a pocket of contaminated strata or a brine pocket.

$$V \frac{\partial C(X,t)}{\partial t} = \lambda_1 f Q_c(t) - \lambda_d V C(X,t) \tag{17}$$

$$Q_c(t) = Q_0 e^{-\lambda_d t} e^{-\lambda_1(t-cl)} \tag{18}$$

where

V = the porosity volume, i.e., the amount of available water (m^3)
$c(X,t)$ = the concentration in V (Ci/m^3)
$Q_c(t)$ = the activity in the affected canisters (Ci)
cl = the canister life (y)

This equation is a balance of the change of activity in the porosity volume with additions and removals of activity from the porosity volume. The porosity volume is the total volume multiplied by the porosity (ε). The solution to the preceding differential equation is:

$$c_1(X,t) = \frac{fQ_0 e^{-\lambda_d t}}{V} \left[1-e^{-\lambda_1(t-cl)}\right] \tag{19}$$

This concentration is the boundary condition at the time the release to the aquifer or land surface begins.

After the release has begun to occur, a similar differential equation describes the change in the activity in the tank.

$$\underset{(1)}{V}\ \underset{(2)}{\frac{\partial C(X,t)}{\partial t}} = \underset{(3)}{\lambda_1 f Q_c(t)} - \underset{(4)}{\lambda_d V C(X,t)} - V(t)C(X,t) \tag{20}$$

V(t) is the volumetric flow rate of the radionuclide to the aquifer. Term 1 is the rate of change of activity in the tank. Term 2 is the input into the tank from the leaching canisters. Term 3 is the radioactive decay in the tank and Term 4 is the annual removal of activity from the repository to the aquifer. Notice that the terms, except the last, are the same as the preceding differential equation. Rearranging and substituting the expression for $Q_c(t)$ we obtain:

$$\frac{\partial C(X,t)}{\partial t} + \left(\lambda_d + \frac{V(t)}{V}\right) C(X,t) = \frac{\lambda_1 f Q_0 e^{-\lambda_d t} e^{-\lambda_1 (t-c1)}}{V} \tag{21}$$

$$p(y) = \lambda_d + V(t)/V \tag{22}$$

$$q(t) = \frac{\lambda_1 f Q_0}{V} e^{-\lambda_d t} e^{-\lambda_1 (t-c1)} \tag{23}$$

$$u(t) = e^{\int^t p(y)dy} \tag{24}$$

Using $u(t)$ as the integrating factor, the general solution is:

$$C(X,t) = \frac{1}{u(t)} \int_{t_e}^{t} u(s)q(s)ds + \frac{C(X,t_e)u(t_e)}{u(t)} \tag{25}$$

where

t_e = the time the release began (event time)

$C(X,t_e^-)$ = the concentration of the nuclide immediately before the release at a point X.

Since the brine pocket is blown to the surface at t_e, $C(X,t_e^+) = 0$ and the last term in the general solution drops out.

The function $\mu(s)$ is calculated in the function DRTGRL. MAXDOSE calls the routine DCADRE (IMSL) to solve the integral in the expression for concentration in this run.

The release rate into the aquifer is the product of the flow rate F_a and appropriate concentration in the repository. Radionuclides released into the aquifer are then dispersed similarly to releases in the direct release to aquifers (K=2).

G. Release to an Aquifer from a Faulting Event which Disturbs the Repository (Functions FLTNHL and FLTNHS, K=7,8)

The last two releases (K=7,8) are similar to the third release type (K=3). A faulting event disturbs the contaminated repository water and releases isotopes to the aquifer system. The only difference between functions 7 and 8 is that 7 is for leach-limited releases while 8 is for solubility-limited releases. For release type 8 the differential equation describing the concentration in the repository water is:

$$V\frac{\partial C(X,t)}{\partial t} = \lambda_1 f Q_c(t) - \lambda_d V C(X,t) - VAQC(X,t) \qquad (26)$$

where:

VAQ = aquifer limited volumetric flow (m^3/y)

The method of solution is the same as the previous case. The last term is similar to the fourth term in the previous case; however, the volumetric flow rate in this case is not a function of time (VAQ). The concentration entering the aquifer is:

$$C(X,t) = \frac{\lambda_1 Q_0 e^{\lambda_1 C l}}{(VAQ-\lambda_1 V)} e^{-(\lambda_d + VAQ/V)t_i} \left[e^{-t_i(\lambda_1 - VAQ/V)} - e^{-t_e(\lambda_1 - VAQ/V)} \right] + \frac{C(X,t_e)\mu(t_e)}{\mu(t_i)} \qquad (27)$$

$$C(X,t_e) = \frac{f\dot{Q}_o\, e^{-\lambda_d t_e}}{V} \left[1-e^{-\lambda_1(t_e-c1)}\right] \qquad (28)$$

$$\mu(t) = e^{(\lambda_d + VAQ/V)t}$$

$$t_i = t_d + t_e - \frac{Ks}{v} \qquad \text{Note - s is the variable of integration.} \qquad (29)$$

The concentration in the aquifer is equal to:

$$C_{AQ}(X,t) = \int_{1.0}^{KX/v} C(X,s)ds \qquad (30)$$

IV. Input Guide for MAXDOSE-EPA Code

The input for Maxdose consists of a job control card, a variable number of title cards, and a variable number of cards in a standard format to enter the data needed to solve the specific problems. In general the standard input deck can be in any order; exceptions will be cited later. Table 1 gives precise data on the input format and table 2 defines input parameters.

In running MAXDOSE, the user arbitrarily selects distances, event times, dose times, and type of repository. From a range of values, the user selects waste characteristics (leach rate, solubility, canister life, inventory), event characteristics (borehole permeability, fault releases, event probabilities), and environmental data (groundwater permeability, porosity, thermal buoyancy gradient, interconnecting gradient, ground water velocity, dispersivity, retardation factors).

However, it is possible for the user to design the repository to his own specifications or change any of the input data (except the radionuclide data) to check the response of the input data changes--a sensitivity analysis.

The output consists of a summary of the input data, dose tables, and a listing of areas contaminated (for nonfault events only).

Job Control Card (Format 1X,5I10)

The user selects the type of release and event, the number of body organs, the number of title cards, the pathways, and repository type.

The job control card will assume default values (except for K) if there are no input values.

Type of release (K=1,2,3,4,5,6,7,8)

There is no default value for K. The user must select one of the following:

1. Drilling release to land surface by direct hit of waste
2. Drilling release to an aquifer by direct hit of waste
3. Release to aquifers by a fault line breaking a row of canisters

4. Drilling or faulting release to surface waters
5. Drilling into a granite tank or brine pocket, debris ejected to land surface
6. Drilling into a granite tank or brine pocket, release to the aquifers

7. Faulting hits a brine pocket (the source term is leach limited)
8. Faulting hits a brine pocket (the source term is solubility limited)

NORGAN

Select the number of organs for which the dose will be calculated (1 or 2). The default value is 1. Organs are selected on card type 31.

NCARDS

Select the number of title cards following the job control card. The default value is 3.

NPATH

Select the pathway to be calculated, usually water or air (the default value is 1). In land surface releases (K=1 or 5), the program will automatically set value to 1. For a surface water release, NPATH must be greater than or equal to 2 (no water doses). (Note that for inhalation calculations NPATH defaults to 1 for breathing and overrides the input.) The pathways are:

Water or air, depending on release	NPATH = 1
Water and Milk	NPATH = 2
Water, Milk, and Crops	NPATH = 3
Water, Milk, Crops, and Beef	NPATH = 4
Water, Milk, Crops, Beef, Fish	NPATH = 5

NREP

The repository types are:

Nonsalt = 1
Bedded Salt = 2
Default = 2

"Nonsalt" repositories include granite, basalt, shale, and dome salt. Repositories are most likely to be sited in granite or bedded salt.

Title Cards (Format 20A4)

As many as NCARDS may be used to enter title, date, data-set name, etc.

Standard Format Cards (Format I2, 7E8.2, 2X, A8, 3A4)

Use these cards to enter the remaining data for the problem. The first entry is a two-digit integer, which indicates the "type" of card being read in. Thus, a card with a "40" in columns 1 and 2 is a "type 40" card. The fields of this card are designated as N1, F(1 through 7), ANUC, and A(1 through 3).

Type 10 card (Distances N1=10)

The distance from the accident site is entered in meters. The code can handle up to 10 distances and can run on any number less than 10. A zero value terminates the list. Seven values for distances can be entered on a type 10 card; three more can be entered on a type 11 card.

Type 11 card (Distances N1=11)

This card is optional and is used only if a more than 7 distances are being used. Enter up to three distance in meters on this card.

Type 20 card (Dose Rate Limits N1=20)

This is an optional card used for aquifer and land surface releases. Enter the minimum dose rate lim ts in rem/y for calculation of areas contaminated by the release. Areas are given in square meters in the output. No zeros can be entered for the array if results are desired. If no areas are desired, leave the type 20 card out of the input deck.

Type 30 card (Radionuclide Data-I N1=30)

There should be only one type 30 card per nuclide per problem. When doing a stacked run however, it may be necessary to input new type 30 cards in the new problem. For more information, see the description of the type 98 card.

Type 30 card must be followed by type 31 and type 32 cards. Data for the same radionuclide must be kept together.

Type 31 card (Radionuclide Data-II N1=31)

All dose factors on this card are input as rem/Ci. The type 31 card is an exception to the general rule that standardized format cards may appear in any order. For every nuclide, the type 31 card must follow a type 30 and precede a type 32 card. The user may use any organ dose conversion factors for organs 1 and 2.

Type 32 card (Radionuclide Data-III N1=32)

Environmental transfer rates obtained from NUREG 1.109 were used. The type 32 card must follow the type 31 for the same nuclide. This is an exception to the general rule that the standardized format cards may appear in any order.

Type 40 card (Miscellaneous Data-I N1=40)

Repository characteristics and data on canisters were taken from Smith (Sm81) and Task D report (EPA79b).

Type 41 card (Miscellaneous Data-II N1=41)

All ingestion and breathing rates are on this card (NUREG 1.109). It is unlikely that a repository would be sited near a surface stream. The value for the average flow rate of a river is not used unless a type 4 event is indicated.

Type 50 card (Aquifer Data N1=50)

This is an optional card, depending on type of release. The porosity of the aquifer and the repository and the initial permeability of the aquifer form the basis for the aquifer velocity.

Type 60 card (Aquifer Gradient Data N1=60)

The first four parameters describe a two-part exponential fit of the hydrologic gradient due to the thermal buoyancy effects of the

repository's heat generation (assuming this to be a spent fuel repository). The fifth parameter is the interconnecting gradient. The numbers below are currently used in EPA's model.

F(1)	=	ALPHA	1.6E-3
F(2)	=	BETA	3.1E-4
F(3)	=	CVA	.132
F(4)	=	CVB	.103
F(5)	=	CVC	.100 (Bedded salt, shale, basalt) 0 (Granite, dome salt)

$$\text{Gradient} = CVA * e^{-ALPHA * t} + CVB * e^{-BETA * t} + CVC$$

Type 70 card (Event Data N1=70)

Required card. The fraction of the total repository affected by the event is entered. A description of the event is entered in columns 61 through 80.

Type 80 card (Event and Dose Time Periods N1=80)

The time the event occurs after the repository is sealed (years). Up to 6 dose time periods can be entered on this card. Up to 13 dose time periods can be entered using types 80 and 81 cards.

Type 81 card (Continuation of Dose times N1=81)

This is an optional card. Up to 7 dose time periods can be entered on this card.

Type 97, 98, 99 cards (Data Separator Cards)

N1=97

Indicates to the program that a new run with non-nuclide data changes will follow. It will keep nuclide data and replace any other card type read in after the 97 card. Following the 97 card, the input is the same as the beginning of the dataset, with only the appropriate data changes. The 97 card does not remove nuclide data.

NI=90

Indicates to the program that a new run with different nuclide data will be run. All values on the new cards must be entered even if all are not being changed (both 97 and 98 cards). The 98 card will clear all nuclide data in storage and new data can be read in (new nuclides or new data for the old nuclides).

NI=99

Required card. Indicates end of run and that no new problem will follow.

Table 1. Input Parameters to MAXDOSE-EPA

Title	Column	Description	Variable	Reference
Job Control Card Format:1X,5I10	11	Type of Release	K=1,2,3,4,5,6,7,8 Default=None	
	21	Number of Organs	NORGAN=1,2 Default=1	
	31	Number of Title Cards	NCARDS=Any number Default=3	
	41	Number of Pathways	NPATH=1,2,3,4,5 Default=1	
	51	Type of Repository	NREP=1,2 Default=2	
Title Card Format: 20A4	1-80	Description of problem (Supplied by user)		
Standard Format Card Format: I2,7E8.2,2X,A8,3A4				
	1-2	Card Type (INTEGER)	NI	
	3-10	FIELD 1 (REAL)	F(1)	
	11-18	FIELD 2 (REAL)	F(2)	
	19-26	FIELD 3 (REAL)	F(3)	
	27-34	FIELD 4 (REAL)	F(4)	
	35-42	FIELD 5 (REAL)	F(5)	
	43-50	FIELD 6 (REAL)	F(6)	
	51-58	FIELD 7 (REAL)	F(7)	
	61-68	FIELD 8 (CHAR)	ANUC	
	69-72	FIELD 9 (CHAR)	A(1)	
	73-76	FIELD 10 (CHAR)	A(2)	
	77-80	FIELD 11 (CHAR)	A(3)	

Note: Fields are left blank if unused, or if default value is desired.

Table 1. Input Parameters to MAXDOSE-EPA--continued

Title	Description	Variable	Reference
Type 10 card (N1=10)	Required. Distances. Up to 7 distances (m) can be entered (Use a type 11 card for additional distances.	DIST(I)=F(I)	
Type 11 card (N1=11)	Optional. Distances (continued) Up to 3 additional distances can be entered.	DIST(7+I)=F(I) DIST(I)	
Type 20 card (N1=20)	Optional. Dose limits. Up to 5 dose levels in increasing order. Associated areas of contamination will be calculated.	DLIM(I)=F(I) DLIM(5)	
Type 30 card (N1=30)	Required. Radionuclide data. Type 31 and 32 cards MUST follow a type 30 card. 1 card per nuclide (20 nuclides)		
	Half life (y)	RNLD=F(1)	
	Inventory of repository at the time it is sealed (Ci)	RNQO=F(2)	Go81
	Soil sink factor (y^{-1})	LAMS=F(3)	Sm80
	Resuspension factor (y^{-1})	RELAMS=F(4)	Sm80
	Retardation factors	RET=F(5)	Sm81
	Solubility of nuclide (Ci/m^3)	SOL=F(6)	Sm81
	Name of nuclide	RNID1=ANUC	
Type 31 card N1=31	Required. Dose conversion factors (DCF). MUST follow type 30 card.		Sm80 Du79 Ki78

Table 1. Input Parameters to MAXDOSE-EPA--continued

Title	Description	Variable	Reference
	DCF for inhaling nuclides in soluble form (Class w) to organ 1.	BRSOL=F(1)	
	Same as above--for organ 2.	BRSOL=F(2)	
	Dose conversion factor for inhaling nuclide in an insoluble form (Class y) to organ 1.	BRINSL=F(3)	
	Same as above--for organ 2.	BRINSL=F(4)	
	DCF for ingesting nuclide to organ 1.	DOSING=F(5)	
	DCF for ingesting nuclide to to organ 2.	DOSING=F(6)	
	Name of nuclide	RNID1=ANUC	
Type 32 card (N1=32)	Required. Environmental transfer rate (ETR). MUST follow type 31 card for same nuclide.		
	ETR from aquifer to crops to dairy cattle to milk	MILK=F(1)	Sm80
	ETR from aquifer to crops	CROPS=F(2)	Sm80
	ETR from aquifer to crops to beef cattle	BEEF=F(3)	Sm80
	ETR from surface waters to fish	FISH=F(4)	Sm80
	Name of nuclide	RNID1=ANUC	

Table 1. Input Parameters to MAXDOSE-EPA--continued

Title	Description	Variable	Reference
Type 40 card (N1=40)	Miscellaneous Data --Card I.		
	Length of repository (m)	LENGTH=F(1)	Sm81
	Widtn of repository (m)	WIDTH=F(2)	Sm81
	Heignt of repository (m)	HEIGHT=F(3)	Sm81
	Area of borehole (m^2)	AREA=F(4)	Sm81
	Leach rate of waste (y^{-1})	XLEACH=F(5)	Sm81 EPA79b
	Canister life (y)	C1=F(6)	Sm81 EPA79b
	Volume of granite tank or brine pocket (m^3)	VTANK=F(7)	Sm81 EPA79b
Type 41 card (N1=41)	Required. Miscellaneous Data-- Card II.		
	Flow rate of surface stream (m^3/y)	FLOW=F(1)	
	Mining fraction in a nonsalt repository	MINEFR=F(2)	EPA79b
	Breathing rate (m^3/y)	BRTHRT=F(3)	ICRP Std man
	Ingestion rate of water, or milk, or beef, or crops (m^3/y)	U=F(4)	NUREG 1.109
	Ingestion rate of fish (m^3/y)	UFISH=F(5)	NUREG 1.109
	Volume of material carried on drill to surface (m^3)	VDRILL=F(6)	

Table 1. Input Parameters to MAXDOSE-EPA--continued

Title	Description	Variable	Reference
Type 50 card (N1=50)	Optional. Aquifer Data Card.		
	Aquifer thickness (m)	B=F(1)	EPA79b
	Diffusion constant in aquifer (m^2/y)	D=F(2)	Go81
	Aquifer velocity (m/y)	MU=F(3)	(*)
	Porosity of the aquifer	EPSAQ=F(4)	EPA79b
	Porosity of the repository	EPSRP=F(5)	EPA79b
	Initial permeability of the aquifer (m/y)	K1=F(6)	EPA79b
	Rate of change of the permeability (m/y^2)	KPRIME=F(7)	EPA79b
Type 60 card (N1=60)	Required. Aquifer Gradient Data		Go81 EPA79b
	The first 4 parameters describe a two-part exponential fit of the hydrologic gradient due to the thermal buoyancy effects of the repository's heat generation (if a spent fuel repository).	ALPHA=F(1) BETA=F(2) CVA=F(3) CVB=F(4)	EPA79b EPA79b EPA79b EPA79b
	Gradient between aquifers over and under the repository. CVC=0 if there is no underlying aquifer --as in granite.	CVC=F(5)	EPA79b
Type 70 card (N1=70)	Required. Event Data Card.		
	Fraction of total repository affected by the event	FRAC=F(1)	EPA79b Sm81
	Event description in columns 61-80. For example: Land Surface Release	RND2=A(1) RND3=A(2) RND4=A(3)	EPA79b EPA79b EPA79b

*Aquifer velocity is based on the porosity of the aquifer, the porosity of the repository, and the initial permeability of the aquifer.

Table 1. Input Parameters to MAXDOSE-EPA--continued

Title	Description	Variable	Reference
Type 80 card (N1=80)	Required. Time periods--event and dose.		
	Time of event. The number of years after the repository is sealed (y).	TEVENT=F(1)	
	Time of dose. The number of years after the event. (Up to 6 dose times can be entered. Use type 81 card for additional 7 entries).	TDOSE(I)=F(I+1)	
Type 81 card (N1=81)	Optional. Time of dose. (Continuation of type 80 card.)	TDOSE(6+I)=F(I)	
Type 97 card (N1=97)	Optional. Data Separator Card. Indicates to the program that a new run will follow with changes to the nonnuclide data. This allows data changes without recompiling. Following the 97 card, the input is the same as the beginning of the dataset, with only the appropriate data changes.		
Type 98 card (N1=98)	Optional. Data Separator Card. Indicates to the program that a new run will follow with different nuclide data. The 98 card will clear all nuclide data in storage and new data can be read in (new nuclides or new data for the old nuclides).		
Type 99 card (N1=99)	Required. End of Run. No problem will follow.		

Table 2. Definitions and Units of Input Parameters to MAXDOSE-EPA

Name	Definition	Units
ALPHA	Hydrologic gradient data	1.6E-3
AREA	Area of borehole	(m^2)
B	Aquifer thickness	(m)
BETA	Hydrologic gradient data	3.1E-4
D	Diffusion constant in the aquifer	(m^2/y)
BEEF	Environmental transfer rates from aquifer to crops to beef cattle	
BRSOL	Dose conversion factor for inhaling radionuclide in soluble form (Class w)	(rem/Ci)
BRINSL	Dose conversion factor for inhaling radionuclide in an insoluble form (Class y)	(rem/Ci)
BRTHRT	Breathing rate	(m^3/y)
Cl	Canister life	(y)
CROPS	Environmental transfer rates from aquifer to crops	
CVA	Hydrologic Gradient Data	.132
CVB	Hydrologic Gradient Data	.103
CVC	Gradient between aquifers over and under the repository. CVC=0, if no underlying aquifer.	.1
D	Diffusion constant in the aquifer	(m^2/y)
DLIM	Dose limits	(rem/y)

Table 2. Definitions and Units of Input Parameters to MAXDOSE-EPA --continued

Name	Definition	Units
DIST	Distance from the release site	(m)
DOSING	Dose conversion factor for ingesting radionuclide	(rem/Ci)
EPSAQ	Porosity of the aquifer	
EPSRP	Porosity of the repository	
FISH	Environmental transfer rates from surface waters to fish	
FLOW	Flow rate of surface stream	(m^3/y)
FRAC	Fraction of total repository inventory released by event	
K	Type of release	
KI	Initial permeability of the aquifer	(m/y)
KPRIME	Rate of change of the permeability	(m/y^2)
HEIGHT	Height of repository	(m)
LAMS	Soil sink factor	(y^{-1})
LENGTH	Length of repository	(m)
MILK	Environmental transfer rate from aquifer to crops to dairy cattle to milk	
MINEFR	Mining fraction in a nonsalt repository	.25
MU	Aquifer velocity	(m/y)
NORGAN	Number of body organs	

Table 2. Definitions and Units of Input Parameters to MAXDOSE-EPA --continued

Name	Definition	Units
NPATH	Pathway	
NREP	Type of repository	
RELAMS	Resuspension factor	(y^{-1})
RET	Retardation factor	
RNID1	Name of radionuclide	
RNLD	Radionuclide half life	(y)
RNQO	Inventory of repository at time it is sealed	(Ci)
SOL	Solubility of nuclide	(Ci/m^3)
TDOSE	Length of time after the event occurs	(y)
TEVENT	Length of time after the repository is sealed	(y)
U	Ingestion rate of water, milk, beef or crops	(m^3/y)
UFISH	Ingestion rate of fish	(m^3/y)
VDRILL	Volume of material carried on drill to surface	(m^3)
VTANK	Volume of granite tank or brine pocket	(m^3)
WIDTH	Width of repository	(m)
XLEACH	Leach rate of canisters	(y^{-1})

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VI. GLOSSARY

Aquifer
Rock or soil strata containing water that reaches the ground surface in any natural or man-made manner.

Basalt
A hard, dense, dark fine-grained igneous rock.

Bedded salt
Salt occurring in strata, commonly interspersed with layers of shale or limestone.

Biosphere
Zone at and adjacent to the earth's surface where all life exists.

Canister
A ceramic container for waste.

Dispersion
The spreading or distribution of a substance from a fixed source through a porous matrix.

Distribution Coefficient
The equilibrium ratio of the quantity of a chemical species adsorbed to a porous media to that in the surrounding solution.

Fault
A break in the continuity of a rock formation caused by a shifting or dislodging of the earth's crust in which adjacent surfaces are differentially displaced parallel to the plane of fracture.

Geosphere
The solid earth, including rocks, soil, and water in the ground, but excluding oceans (hydrosphere) and air (atmosphere).

Half-Life
The time required for one half of an initially radioactive material to undergo nuclear transformation; half-life is a measure of the persistence of radioactivity and is unique to each radionuclide.

High-level waste:
The highly radioactive waste resulting from the reprocessing of spent fuel to separate uranium and plutonium from the fission products. The term includes the high-level liquid wastes (HLLW) produced directly in reprocessing, and the solid high-level wastes (HLW) which can be made therefrom.

Hydrologic gradient
The rate of change of the pressure of groundwater with respect to distance. The pressure drop per unit length of distance traveled.

Interstitial velocity
The velocity of groundwater flow through the pores and openings and around individual grains of geologic media.

Leaching
Extracting material from a solid by contacting it with water or with a solution.

Permeability
The ability of a fluid to move through a medium under a hydrologic gradient.

Porosity
The ratio of the volume of interstices of a material to its total volume.

Radionuclide
A general term that applied to all atomic forms of the elements. "Isotopes" are the various forms of a single element; hence a family of nuclides comprises all the isotopic forms of all the elements.

Rem
A dose unit which takes into account the relative biological effectiveness (RBE) of the radiation. The rem is defined as the dose of a particular type of radiation required to produce the same biological effect as one roentgen of (0.25Mev) gamma radiation. A 1-rad dose of alpha particles is approximately equivalent in its biological effects to 10 rads of gamma radiation, and hence may be expressed as 10 rems. A millirem (mrem) is one thousandth of a rem.

Retardation factor
Ratio of the water velocity to the nuclide migration velocity.

Salt dome
A geologic salt formation in which a plug of salt has been thrust up through rock at some depth, leading to a subterranean "cylinder" of salt which may be a mile or more in diameter and several miles deep.

Source term
The amounts of specific radioactive nuclides issuing from a process or from a process step.

Tank
The region of contaminated backfill in the repository.

APPENDIX A

LISTING OF MAXDOSE

CODE

```
00001         BLOCK DATA
00002         COMMON /BLOCK1/ DOSERT(21,13,10,5,2)
00003         COMMON /BLOCK2/ REM(13,10,5,2),  PCT(13,10,5,2), NAME(13,10,5,2),
00004        1                      DIST(10)
00005         COMMON /BLOCK3/ A2,A3,T,V
00006         COMMON /BLOCK4/ K1,KPRIME,CVA,CVB,CVC,ALPHA,BETA,AREA
00007         COMMON /BLOCK5/ RET(21),XLEACH,B,MU,EPSAQ,WIDTH,HEIGHT,LENGTH,
00008        1                MINEFR,CL,K,TDOSE(13),EPSRP
00009         COMMON /BLOCK6/ TEVENT,RNLD(21),SOL(21)
00010         COMMON /BLOCK7/ NNUC,NTIME,FRAC
00011         COMMON /BLOCK8/ DLIM(5),D,RNQO(21)
00012         REAL *8 NAME
00013         REAL MU,MINEFR,LENGTH,K1,KPRIME
00014         END
00015  C
00016  C      IDLIM DEFAULTS TO 1
00017  C
00018         COMMON /BLOCK1/ DOSERT(21,13,10,5,2)
00019         COMMON /BLOCK2/ REM(13,10,5,2),  PCT(13,10,5,2), NAME(13,10,5,2),
00020        1                      DIST(10)
00021         COMMON /BLOCK4/ K1,KPRIME,CVA,CVB,CVC,ALPHA,BETA,AREA
00022         COMMON /BLOCK5/ RET(21),XLEACH,B,MU,EPSAQ,WIDTH,HEIGHT,LENGTH,
00023        1                MINEFR,CL,K,TDOSE(13),EPSRP
00024         COMMON /BLOCK6/ TEVENT,RNLD(21),SOL(21)
00025         COMMON /BLOCK7/ NNUC,NTIME,FRAC
00026         COMMON /BLOCK8/ DLIM(5),D,RNQO(21)
00027         DIMENSION   LAMS(21),     RELAMS(21),     RNID1(21),
00028        1           RNID2(21),    RNID3(21),      RNID4(21),
00029        2               A(3),     TITLE(20),    BRSOL(2,21),  BRINSL(2,21),
00030        3        DOSING(2,21),    CROPS(21),      BEEF(21),      MILK(21),
00031        4          FISH(21),        F(10),                   CONC(21,13,10),
00032        5    MAXNUC(13,10,5,2)
00033         REAL *4 RNID2,RNID3,RNID4,TITLE,A,RND2,RND3,RND4
00034         REAL *8 RNID1,ANUC,RND1,NAME,NONE
00035         REAL K1,KPRIME,MINEFR,LENGTH,MU,LAMS,MILK
00036         DATA NONE/8HNONE    /,NRN30/0/,NRN31/0/,NRN32/0/
00037  C#####################################################################
00038  C#                                                                   #
00039  C#               JOB  CONTROL  CARDS                                 #
00040  C#                                                                   #
00041  C#####################################################################
```

```
00042     50 READ(5,99) K,NORGAN,NCARDS,NPATH,NREP
00043        IF(K .GT. 8) WRITE(6,1200)
00044        IF(K .GT. 8) GO TO 9999
00045        IF(NREP .EQ. 0) NREP = 2
00046        IF(NORGAN .GT. 2) NORGAN = 2
00047        IF(NPATH  .GT. 5) NPATH  = 5
00048        IF(NPATH .EQ. 0)  NPATH = 1
00049        IF(K .EQ. 4   .AND.   NPATH .EQ. 1)   NPATH = 2
00050        IF(K .EQ. 1  .OR. K .EQ. 5) NPATH = 1
00051        IF(NORGAN .EQ. 0) NORGAN = 1
00052        IF(NCARDS .EQ. 0) NCARDS = 3
00053        WRITE(6,100) K,NORGAN,NCARDS,NPATH,NREP
00054     99 FORMAT(1X,5I10)
00055    100 FORMAT(1H1,1X,5I10)
00056   C##############################################################################
00057   C#                                                                            #
00058   C#                    TITLE     CARDS                                        #
00059   C#                                                                            #
00060   C##############################################################################
00061        DO 200 I = 1,NCARDS
00062        READ(5,300) (TITLE(KKK),KKK=1,20)
00063        WRITE(6,301) (TITLE(KKK),KKK=1,20)
00064     200 CONTINUE
00065     300 FORMAT(20A4)
00066     301 FORMAT(1X,20A4)
00067     350 READ(5,400) N1,(F(I),I = 1,7),ANUC,(A(I),I = 1,3)
00068         WRITE(6,500) N1,(F(I),I = 1,7),ANUC,(A(I),I = 1,3)
00069     400 FORMAT(I2,7E8.2,2X,A8,3A4)
00070     500 FORMAT(1H ,I2,4X,7(2X,1PE10.2),2X,A8,3A4)
00071   C##############################################################################
00072   C#                                                                            #
00073   C#    TYPE 10 AND 11 CARDS ENTER DISTANCES OF DOSE CALCULATIONS               #
00074   C#                                                                            #
00075   C##############################################################################
00076        IF(N1 .NE. 10) GO TO 550
00077        DO 549 I = 1,7
00078        IF(F(I) .NE. 0.0)  LDIST = I
00079        DIST(I) = F(I)
00080     549 CONTINUE
00081        GO TO 350
00082     550 IF(N1 .NE. 11) GO TO 600
00083        DO 599 I = 1,3
00084        IF(F(I) .NE. 0.0)  LDIST = LDIST + 1
00085        DIST(I + 7) = F(I)
00086     599 CONTINUE
00087        GO TO 350
```

```
C#########################################################################
C#                                                                       #
C#        TYPE 20 CARDS ENTER DOSE LIMITS FOR CONTAMINATED AREAS         #
C#                                                                       #
C#########################################################################
  600 IF(N1 .NE. 20) GO TO 650
      DO 649 I = 1,5
      DLIM(I) = F(I)
      H = H + DLIM(I)
  649 CONTINUE
      IF(H .GT. 0.0) IDLIM = 0
      GO TO 350
C#########################################################################
C#                                                                       #
C#              TYPE 30 CARDS ENTER NUCLIDE DATA                         #
C#                                                                       #
C#########################################################################
  650 IF(N1 .NE. 30) GO TO 700
      DO 659 I = 1,20
      IF(RNLD(I) .EQ. 0.0) GO TO 660
      IF(RNLD(I) .NE. .693/F(1)) GO TO 659
      RNLD(I)    =   .693/F(1)
      RNQO(I)    =    F(2)
      LAMS(I)    =    F(3)
      RELAMS(I)  =    F(4)
      RET(I)     =    F(5)
      SOL(I)     =    F(6)
      RNID1(I)   =    ANUC
      RNID2(I)   =    A(1)
      RNID3(I)   =    A(2)
      RNID4(I)   =    A(3)
  659 CONTINUE
      GO TO 350
  660 NRN30 = NRN30 + 1
      RNLD(NRN30)   =    .693/F(1)
      RNQO(NRN30)     =       F(2)
      LAMS(NRN30)      =      F(3)
      RELAMS(NRN30)      =    F(4)
      RET(NRN30)      =       F(5)
      SOL(NRN30)       =      F(6)
      RNID1(NRN30)       =    ANUC
      RNID2(NRN30)       =    A(1)
      RNID3(NRN30)       =    A(2)
      RNID4(NRN30)       =    A(3)
      GO TO 350
```

```
00133 C#########################################################################
00134 C#                                                                       #
00135 C#       TYPE 31 CARDS ENTER DOSE CONVERSION FACTORS FOR NUCLIDES        #
00136 C#                                                                       #
00137 C#########################################################################
00138   700 IF(N1 .NE. 31) GO TO 750
00139       NRN31 = NRN31 + 1
00140       BRSOL(1,NRN31)   =   F(1)
00141       BRSOL(2,NRN31)   =   F(2)
00142       BRINSL(1,NRN31)  =   F(3)
00143       BRINSL(2,NRN31)  =   F(4)
00144       DOSING(1,NRN31)  =   F(5)
00145       DOSING(2,NRN31)  =   F(6)
00146       RNID1(NRN31)     =    ANUC
00147       RNID2(NRN31)     =    A(1)
00148       RNID3(NRN31)     =    A(2)
00149       RNID4(NRN31)     =    A(3)
00150       GO TO 350
00151 C#########################################################################
00152 C#                                                                       #
00153 C#         TYPE 32 CARDS ENTER ENVIRONMENTAL TRANSFER FACTORS            #
00154 C#                                                                       #
00155 C#########################################################################
00156   750 IF(N1 .NE. 32) GO TO 800
00157       NRN32 = NRN32 + 1
00158       MILK(NRN32)     =    F(1)
00159       CROPS(NRN32)    =    F(2)
00160       BEEF(NRN32)     =    F(3)
00161       FISH(NRN32)     =    F(4)
00162       RNID1(NRN32)    =    ANUC
00163       GO TO 350
00164 C#########################################################################
00165 C#                                                                       #
00166 C#       TYPE 40 CARDS ENTER MISC. DATA FOR THE REPOSITORY SITE          #
00167 C#                                                                       #
00168 C#########################################################################
00169   800 IF(N1 .NE. 40) GO TO 825
00170       LENGTH    =   F(1)
00171       WIDTH     =   F(2)
00172       HEIGHT    =   F(3)
00173       AREA      =   F(4)
00174       XLEACH    =   F(5)
00175       CL        =   F(6)
00176       VTANK     =   F(7)
00177       GO TO 350
```

```
00178 C#########################################################################
00179 C#                                                                       #
00180 C#              TYPE 41 CARDS ENTER MORE MISC. DATA                      #
00181 C#                                                                       #
00182 C#########################################################################
00183   825 IF(N1. NE. 41) GO TO 850
00184       FLOW   =   F(1)
00185       MINEFR  =  F(2)
00186       BRTHRT  =  F(3)
00187       U      =   F(4)
00188       UFISH   =  F(5)
00189       VDRILL  =  F(6)
00190       GO TO 350
00191 C#########################################################################
00192 C#                                                                       #
00193 C#               TYPE 50 CARDS ENTER AQUIFER DATA                        #
00194 C#                                                                       #
00195 C#########################################################################
00196   850 IF(N1 .NE. 50) GO TO 900
00197       B     =    F(1)
00198       D     =    F(2)
00199       MU    =    F(3)
00200       EPSAQ   =   F(4)
00201       EPSRP   =   F(5)
00202       K1     =    F(6)
00203       KPRIME  =   F(7)
00204       GO TO 350
00205 C#########################################################################
00206 C#                                                                       #
00207 C#             TYPE 60 CARDS ENTER HYDRAULIC GRADIENT DATA               #
00208 C#                                                                       #
00209 C#########################################################################
00210   900 IF(N1 .NE. 60) GO TO 950
00211       ALPHA   =   F(1)
00212       BETA    =   F(2)
00213       CVA     =   F(3)
00214       CVB     =   F(4)
00215       CVC     =   F(5)
00216       GO TO 350
```

```
00217  C#########################################################################
00218  C#                                                                       #
00219  C#              TYPE 70 CARDS ENTER EVENT DATA                           #
00220  C#                                                                       #
00221  C#########################################################################
00222    950 IF(N1 .NE. 70) GO TO 1000
00223        FRAC  =   F(1)
00224        RND1  =   ANUC
00225        RND2  =   A(1)
00226        RND3  =   A(2)
00227        RND4  =   A(3)
00228        GO TO 350
00229  C#########################################################################
00230  C#                                                                       #
00231  C#         TYPES 80 AND 81 CARDS ENTER EVENT TIME AND DOSE TIMES         #
00232  C#                                                                       #
00233  C#########################################################################
00234   1000 IF(N1 .NE. 80) GO TO 1050
00235        TEVENT  =  F(1)
00236        DO 1049 I = 1,6
00237        IF(F(I+1) .NE. 0.0)  LTIME = I
00238        TDOSE(I)  =  F(I + 1)
00239   1049 CONTINUE
00240        GO TO 350
00241   1050 IF(N1 .NE. 81) GO TO 1101
00242        DO 1100 I = 1,7
00243        IF(F(I) .NE. 0.0)  LTIME = LTIME + 1
00244        TDOSE(I + 6)  =  F(I)
00245   1100 CONTINUE
00246        GO TO 350
00247   1101 IF(N1 .EQ. 97) GO TO 1110
00248        NRN30 = NRN30 + 1
00249        NRN31 = NRN31 + 1
00250        NRN32 = NRN32 + 1
00251        RNLD(NRN30)    =      1.0
00252        RNQO(NRN30)    =      0.0
00253        LAMS(NRN30)    =      0.0
00254        RELAMS(NRN30)  =      0.0
00255        RET(NRN30)       =      1.0
00256        SOL(NRN30)       =      0.0
00257        RNID1(NRN30)     =     NONE
00258        BRSOL(1,NRN31)   =      0.0
00259        BRSOL(2,NRN3 )   =      0.0
00260        BRINSL(1,NRN31)  =      0.0
00261        BRINSL(2,NRN31)  =      0.0
00262        DOSING(1,NRN31)  =      0.0
00263        DOSING(2,NRN31)  =      0.0
00264        MILK(NRN32)      =      0.0
00265        CROPS(NRN32)     =      0.0
00266        BEEF(NRN32)      =      0.0
```

```
00267        FISH(NRN32)     =     0.0
00268   1110 IF(N1 .EQ. 97  .OR.   N1 .EQ. 98   .OR.   N1 .EQ. 99)   GO TO 1300
00269        WRITE(6,1200)
00270   1200 FORMAT(1H1,'***PROBLEM TERMINATED DUE TO INPUT ERRORS,CHECK THE',
00271       1'VALUE OF THE FIRST ENTRY ON THE JOB CONTROL CARD,MAKE SURE THE',
00272       2'INPUT IS IN THE CORRECT FORMAT***')
00273        GO TO 9999
00274   1300 CONTINUE
00275        IF(VDRILL .EQ. 0.0)  VDRILL = VTANK
00276  C#########################################################################
00277  C#                                                                       #
00278  C#            START LOOPS AROUND NUCLIDES(NNUC), DOSE                    #
00279  C#            TIMES(NTIME), AND DISTANCES(NDIST)                         #
00280  C#                                                                       #
00281  C#########################################################################
00282  C
00283  C
00284  C     FUNCTION  1)AIR:MODELS A SLUG RELEASE TO THE LAND SURFACE BY THE
00285  C                    DRILL BIT.
00286  C
00287  C
00288  C               2)  DRILLH  :  MODELS A DIRECT HIT OF A WASTE CANISTER
00289  C
00290  C
00291  C               3) FLTH : MODELS A DIRECT HIT OF A LINE OF CANISTERS BY
00292  C                    A FAULT LINE.
00293  C
00294  C
00295  C               4)   STREAM : MODELS A RELEASE TO SURFACE WATER STREAMS
00296  C
00297  C
00298  C               5) DRNHLS:MODELS A DRILLING RELEASE TO THE LAND SURFACE
00299  C                      BY WAY OF A BRINE POCKET(SALT) OR GRANITE.
00300  C
00301  C
00302  C               6)  DRNHAQ : MODELS A DRILLING RELEASE TO THE AQUIFERS.
00303  C                      BY WAY OF A BRINE POCKET(SALT) OR GRANITE.
00304  C
00305  C
00306  C               7) FLTNHL : MODELS FAULTING,NOT A DIRECT HIT,THE SOURCE
00307  C                      TERM IS LEACH LIMITED.
00308  C
00309  C
00310  C               8) FLTNHS : SAME AS PREVIOUS FUNCTION  EXCEPT THAT THE
00311  C                      SOURCE IS SOLUBILITY LIMITED.
00312  C
```

```
00313  C
00314         IORGAN  =  NORGAN
00315         IPATH   =   NPATH
00316         NORGAN = 1
00317         NPATH  = 1
00318         DO 2000 NNUC = 1,NRN30
00319          DO 2000 NTIME = 1,LTIME
00320           DO 2000 NDIST = 1,LDIST
00321  C
00322  C
00323                 IF(K .EQ. 1) CONC(NNUC,NTIME,NDIST) = AIR(RNQO(NNUC),
00324        1        TDOSE(NTIME),DIST(NDIST),RNLD(NNUC),LAMS(NNUC),
00325        2        RELAMS(NNUC),TEVENT,FRAC)
00326  C
00327  C
00328                 IF(K .EQ. 2) CONC(NNUC,NTIME,NDIST) = DRILLH (RNQO(NNUC),
00329        1       TDOSE(NTIME),DIST(NDIST),RNLD(NNUC),RET(NNUC),MU,TEVENT,
00330        2       XLEACH,D,B,EPSAQ,FRAC,SOL(NNUC),AREA,K1,KPRIME,CVA,CVB,CVC,
00331        3        ALPHA,BETA)
00332  C
00333  C
00334                 IF(K .EQ. 3) CONC(NNUC,NTIME,NDIST) = FLTH(RNQO(NNUC),
00335        1        TDOSE(NTIME),RNLD(NNUC),DIST(NDIST),RET(NNUC),MU,TEVENT,
00336        2        XLEACH,D,B,EPSAQ,FRAC,SOL(NNUC),CL,LENGTH,WIDTH,HEIGHT,
00337        3        MINEFR)
00338  C
00339  C
00340                 IF(K .EQ. 4) CONC(NNUC,NTIME,NDIST) = STREAM(RNQO(NNUC),
00341        1        TDOSE(NTIME),RNLD(NNUC),TEVENT,XLEACH,FRAC,SOL(NNUC),K1,
00342        2        KPRIME,AREA,CVC,FLOW)
00343  C
00344  C
00345                 IF(K .EQ. 5) CONC(NNUC,NTIME,NDIST) = DRNHLS(RNQO(NNUC),
00346        1        TDOSE(NTIME),DIST(NDIST),RNLD(NNUC),TEVENT,XLEACH,FRAC,
00347        2        SOL(NNUC),VTANK,VDRILL,LAMS(NNUC),RELAMS(NNUC),CL)
00348  C
00349  C
00350                 IF(K .EQ. 6) CONC(NNUC,NTIME,NDIST) = DRNHAQ(RNQO(NNUC),
00351        1       TDOSE(NTIME),NREP,DIST(NDIST),RNLD(NNUC),RET(NNUC),MU,
00352        2       TEVENT,XLEACH,D,B,EPSAQ,SOL(NNUC),CL,AREA,K1,KPRIME,CVA,CVB,
00353        3        CVC,ALPHA,BETA,LENGTH,WIDTH,HEIGHT,MINEFR,VTANK,FRAC,
00354        4        EPSRP)
00355  C
00356  C
00357                 IF(K .EQ. 7) CONC(NNUC,NTIME,NDIST) = FLTNHL(TEVENT,
00358        1        TDOSE(NTIME),RNQO(NNUC),MU,RET(NNUC),DIST(NDIST),
00359        2        CL,XLEACH,FRAC,LENGTH,B,EPSAQ,D,WIDTH,SOL(NNUC),HEIGHT,
00360        3        MINEFR)
00361  C
```

```
00362  C
00363                IF(K .EQ. 8) CONC(NNUC,NTIME,NDIST) = FLTNHS(TEVENT,
00364       1        TDOSE(NTIME),RNQO(NNUC),MU,RET(NNUC),DIST(NDIST),
00365       2        CL,XLEACH,FRAC,LENGTH,B,EPSAQ,D,WIDTH,SOL(NNUC),HEIGHT,
00366       3        MINEFR)
00367  C
00368  C
00369                DO 2000 NPATH = 1,IPATH
00370                 DO 2000 NORGAN = 1,IORGAN
00371                          DOSERT(NNUC,NTIME,NDIST,NPATH,NORGAN) =
00372       1                  DOSE(CONC(NNUC,NTIME,NDIST),DOSING(NORGAN,NNUC),
00373       2                  BRINSL(NORGAN,NNUC),BRSOL(NORGAN,NNUC),
00374       3                  MILK(NNUC),CROPS(NNUC),BEEF(NNUC),FISH(NNUC),
00375       4                  NPATH,U,BRTHRT,UFISH)
00376  C
00377  C
00378   2000 CONTINUE
00379  C
00380  C
00381  C#########################################################################
00382  C#                                                                       #
00383  C#            LOOPS WILL FIND THE MAXIMUM CONTRIBUTOR                    #
00384  C#            TO A GIVEN ORGAN ALONG A GIVEN DOSE PATH                   #
00385  C#            AT A GIVEN DISTANCE AND TIME.                              #
00386  C#                                                                       #
00387  C#########################################################################
00388        DO 3000 NTIME = 1,LTIME
00389         DO 3000 NDIST = 1,LDIST
00390          DO 3000 NPATH = 1,IPATH
00391           DO 3000 NORGAN = 1,IORGAN
00392  C
00393  C
00394                MAXNUC(NTIME,NDIST,NPATH,NORGAN)=
00395       1        MAXI(DOSERT(1,NTIME,NDIST,NPATH,NORGAN),NRN30)
00396                IMAX = MAXNUC(NTIME,NDIST,NPATH,NORGAN)
00397                NAME(NTIME,NDIST,NPATH,NORGAN) = RNID1(IMAX)
00398  C
00399             DO 3000 NNUC = 1,NRN30
00400                REM(NTIME,NDIST,NPATH,NORGAN) =
00401       1        REM(NTIME,NDIST,NPATH,NORGAN) + DOSERT(NNUC,NTIME,NDIST,
00402       2                                                NPATH,NORGAN)
00403   3000 CONTINUE
00404  C
```

```
00405  C
00406  C#########################################################################
00407  C#                                                                       #
00408  C#            THE NEXT LOOPS WILL CALCULATE THE % OF                     #
00409  C#            THE MAXIMUM CONTRIBUTOR TO THE DOSE                        #
00410  C#                                                                       #
00411  C#########################################################################
00412  C
00413        DO 4000 NTIME = 1,LTIME
00414         DO 4000 NDIST = 1,LDIST
00415          DO 4000 NPATH = 1,IPATH
00416           DO 4000 NORGAN = 1,IORGAN
00417  C
00418                IMAX = MAXNUC(NTIME,NDIST,NPATH,NORGAN)
00419                IF(REM(NTIME,NDIST,NPATH,NORGAN) .NE. 0)  GO TO 3100
00420                PCT(NTIME,NDIST,NPATH,NORGAN) = 0.0
00421                GO TO 4000
00422   3100         PCT(NTIME,NDIST,NPATH,NORGAN) = 100 *
00423       1        DOSERT(IMAX,NTIME,NDIST,NPATH,NORGAN) /
00424       2        REM(NTIME,NDIST,NPATH,NORGAN)
00425  C
00426  C
00427   4000 CONTINUE
00428  C
00429  C
00430  C
00431  C
00432  C
00433  C
00434  C#########################################################################
00435  C#                                                                       #
00436  C#            OUTPUT WILL PRINT THE DOSERATE,MAXIMUM CONTRIBUTOR         #
00437  C#            TO THE DOSE,AND THE % CONTRIBUTION.                        #
00438  C#                                                                       #
00439  C#########################################################################
00440  C
00441  C
00442               CALL OUTPUT (IPATH,IORGAN,TEVENT,RND1,RND2,RND3,RND4,MU,
00443       1                    LTIME,LDIST,IDLIM)
00444  C
00445  C
00446  C
00447  C
00448        IF(N1 .EQ. 99) GO TO 9999
00449        IF(N1 .EQ. 97  .OR  .N1 .EQ. 98) CALL INIT(NRN30,IPATH,IORGAN)
00450        IF(N1 .EQ. 97) GO TO 50
00451        NRN30 = 0
00452        NRN31 = 0
00453        NRN32 = 0
00454        GO TO 50
00455   9999 STOP
00456        END
```

```
00457  C
00458  C
00459  C
00460  C
00461  C
00462        FUNCTION  AIR(RNQO,TDOSE,DIST,RNLD,XLAMS,RELAMS,TEVENT,FRAC)
00463  C
00464        C1 = FRAC * RNQO * EEXP(-RNLD * TEVENT)
00465        C2 = 2.5E-17 * ((DIST/1000)**(-1.43))
00466        C3 = EEXP(-(DIST / 9595) ** (.57))
00467        C4 = -TDOSE * (RNLD + XLAMS + RELAMS)
00468        C5 = EEXP(C4)
00469        AIR = C1 * C2 * C3 * C5
00470  C
00471  C
00472        RETURN
00473        END
00474  C
00475  C
00476  C
00477  C
00478        FUNCTION  DRILLH(RNQO,TDOSE,DIST,RNLD,RET,MU,TEVENT,XLEACH,D,B,
00479       1        EPSAQ,FRAC,SOL,AREA,K1,KPRIME,CVA,CVB,CVC,ALPHA,BETA)
00480  C
00481        REAL MU,K1,KPRIME
00482        C1 = DIST * RET / MU
00483        C2 = TEVENT + TDOSE
00484        IF(TDOSE - C1) 100,200,200
00485    100 DRILLH = 0.0
00486        GO TO 300
00487    200 C3 = -RNLD * C2
00488        C4 = -XLEACH * (TDOSE - C1)
00489        C5 = 1.0 / (SQRT(12.56 * D * MU * DIST) * B * EPSAQ)
00490        C6 = FRAC * XLEACH * RNQO * EEXP(C3 + C4)
00491        C7 = SOL * EEXP(-RNLD * C1)
00492        C8 = AREA * (K1 + KPRIME * (TDOSE - C1)) *
00493       1     (CVA * EEXP( -ALPHA * (C2 - C1)) +
00494       2      CVB * EEXP( - BETA * (C2 - C1)) + CVC)
00495        C9 = C7 * C8
00496        D1 = C6
00497        IF(SOL .NE. 0) D1 = AMIN1(C6,C9)
00498        DRILLH = D1 * C5
00499  C
00500    300 CONTINUE
00501  C
00502        RETURN
00503        END
```

```
00504  C
00505  C
00506  C
00507  C
00508        FUNCTION  FLTH(RNQO,TDOSE,RNLD,DIST,RET,MU,TEVENT,XLEACH,D,B,
00509       1         EPSAQ,FRAC,SOL,CL,LENGTH,WIDTH,HEIGHT,MINEFR)
00510  C
00511        REAL MU,LENGTH,MINEFR,DCADRE,FLTGRL,AERR,RERR,ERROR
00512        INTEGER IER
00513        EXTERNAL FLTGRL
00514        AERR = 0.0
00515        RERR = 0.095
00516        IF(TEVENT . LT. CL) TEVENT = CL
00517        C1 = TDOSE * MU / RET
00518        IF(C1 .GT. DIST) C1 = DIST
00519        IF(C1 .LT. 1.0) FLTH = 0.0
00520        IF(C1 .LT. 1.0) GO TO 200
00521        C2 = DCADRE(FLTGRL,1.0,C1,AERR,RERR,ERROR,IER)
00522        FLTH = C2
00523  C
00524    200 CONTINUE
00525  C
00526        RETURN
00527        END
00528  C
00529  C
00530  C
00531  C
00532        FUNCTION  STREAM(RNQO,TDOSE,RNLD,TEVENT,XLEACH,FRAC,SOL,K1,
00533       1         KPRIME,AREA,CVC,FLOW)
00534  C
00535        REAL K1,KPRIME
00536        C1 = XLEACH * RNQO * FRAC
00537        C2 = -RNLD * TEVENT
00538        C3 = -(RNLD + XLEACH) * TDOSE
00539        C4 = (K1 + KPRIME * TDOSE) * SOL * AREA * CVC
00540        C5 = C3
00541        IF(SOL .NE. 0) C5 = AMIN1(C3,C4)
00542        STREAM = C1 * EEXP(C2 + C3) / FLOW
00543  C
00544  C
00545        RETURN
00546        END
00547  C
00548  C
00549  C
```

```
00550  C
00551        FUNCTION  DRNHLS(RNQO,TDOSE,DIST,RNLD,TEVENT,XLEACH,FRAC,SOL,
00552       1        VTANK,VDRILL,XLAMS,RELAMS,CL)
00553  C
00554        IF(TEVENT .LT. CL) C6 = 0.0
00555        IF(TEVENT .LT. CL) GO TO 200
00556        C1 = TEVENT - CL
00557        C2 = -C1 * XLEACH
00558        C3 = 1 - EEXP(C2)
00559        C4 = -RNLD * TEVENT
00560        C5 = FRAC * RNQO * C3 * EEXP(C4)
00561        C6 = C5 * VDRILL / VTANK
00562        SOLCI = SOL * VDRILL
00563        IF(SOL .NE. 0) GO TO 100
00564        GO TO 200
00565    100 C6 = AMIN1(C6,SOLCI)
00566    200 C7 = (2.5E-17) * ((DIST/1000)**(-1.43))
00567        C8 = EEXP(-(DIST/9595)**(.57))
00568        C9 = EEXP(-(RNLD + XLAMS + RELAMS) * TDOSE)
00569        DRNHLS = C6 * C7 * C8 * C9
00570  C
00571  C
00572        RETURN
00573        END
00574  C
00575  C
00576  C
00577  C
00578        FUNCTION  DRNHAQ(RNQO,TDOSE,NREP,DIST,RNLD,RET,MU,TEVENT,XLEACH,
00579       1        D,B,EPSAQ,SOL,CL,AREA,K1,KPRIME,CVA,CVB,CVC,ALPHA,BETA,
00580       2        LENGTH,WIDTH,HEIGHT,MINEFR,VTANK,FRAC,EPSRP)
00581  C
00582        REAL MU,K1,KPRIME,LENGTH,MINEFR,DCADRE,DRTGRL,AERR,RERR,ERROR
00583        COMMON /BLOCK3/ A2,A3,T,V
00584        INTEGER IER
00585        EXTERNAL DRTGRL
00586        T = TEVENT + TDOSE - DIST * RET / MU
00587        T1 = T - TEVENT
00588        IF(T1 .LT. 0.0   .OR.    RNQO .EQ. 0.0) DRNHAQ = 0.0
00589        IF(T1 .LT. 0.0   .OR.    RNQO .EQ. 0.0) GO TO 300
00590        IF(TEVENT .LT. CL) DRNHAQ = 0.0
00591        IF(TEVENT .LT. CL) GO TO 300
00592        GO TO (100,200),NREP
00593    100 V = LENGTH * WIDTH * HEIGHT * EPSRP * MINEFR
00594        C0 = TEVENT + TDOSE
00595        C1 = DIST * RET / MU
00596        C2 = 1.0 / (SQRT(12.56 * D * MU * DIST) * B * EPSAQ)
00597        C3 = SOL * EEXP( -RNLD * C1)
00598        C4 = AREA * (K1 + KPRIME * T1)
```

```
00599          C5 = CVA * EEXP( -ALPHA * (C0 - C1))
00600          C6 = CVB * EEXP( - BETA * (C0 - C1))
00601          C7 = C4 * (C5 + C6 + CVC)
00602          C8 = C3 * C7
00603          C9 = C7 * RNQO / V
00604          D1 = 1 - EEXP((CL + C1 - C0) * XLEACH)
00605          D2 = EEXP( -RNLD * (C0 - C1))
00606          D3 = C9 * D1 * D2
00607          D4 = D3 * FRAC
00608          IF(SOL .NE. 0) D4 = AMIN1(D4,C8)
00609          DRNHAQ = D4 * C2 * EEXP(-RNLD * C1)
00610          GO TO 300
00611      200 V = VTANK
00612          A1 = XLEACH * FRAC * RNQO * EEXP(XLEACH * CL) / V
00613          A2 = ALOG(A1)
00614          A3 =  - XLEACH
00615          RERR = .095
00616          AERR = 0.0
00617          A4 = DCADRE(ORTGRL,TEVENT,T,AERR,RERR,ERROR,IER)
00618          A5 = K1 + KPRIME * T1
00619          A6 = CVA * EEXP( -ALPHA * T)
00620          A7 = CVB * EEXP( - BETA * T) + CVC
00621          A8 = AREA / (SQRT(12.56 * D * MU * DIST) * B * EPSAQ)
00622          A9 = A5 * (A6 + A7) * A8
00623          DRNHAQ = A4
00624          IF(SOL .NE. 0) DRNHAQ = AMIN1(SOL,DRNHAQ)
00625          DRNHAQ = A9 * DRNHAQ * EEXP( -RNLD * DIST * RET / MU)
00626      300 CONTINUE
00627          RETURN
00628          END
00629  C
00630  C
```

```
00631  C
00632  C
00633        FUNCTION  FLTNHL(TEVENT,TDOSE,RNQO,MU,RET,DIST,CL,
00634       1         XLEACH,FRAC,LENGTH,B,EPSAQ,D,WIDTH,SOL,HEIGHT,MINEFR)
00635  C
00636        REAL MU,LENGTH,MINEFR
00637        EXTERNAL FLTGRL
00638        AERR = 0.0
00639        RERR = 0.095
00640        C1 = TDOSE * MU / RET
00641        IF(C1 .GT. DIST) C1 = DIST
00642        IF(TEVENT .LT. CL) TEVENT = CL
00643        IF(C1 .LT. 1.0) FLTNHL = 0.0
00644        IF(C1 .LT. 1) GO TO 100
00645        C2 = RNQO * FRAC
00646        C3 = 1.0 / SQRT(12.56 * D * MU)
00647        C4 = DCADRE(FLTGRL,1.0,C1,AERR,RERR,ERROR,IER)
00648        FLTNHL = C2 * C3 * C4
00649  C
00650    100 CONTINUE
00651  C
00652        RETURN
00653        END
00654  C
00655  C
00656  C
00657  C
00658        FUNCTION  FLTNHS(TEVENT,TDOSE,RNQO,MU,RET,DIST,CL,
00659       1         XLEACH,FRAC,LENGTH,B,EPSAQ,D,WIDTH,SOL,HEIGHT,MINEFR)
00660  C
00661        REAL MU,LENGTH,MINEFR
00662        EXTERNAL FLTGRL
00663        AERR = 0.0
00664        RERR = 0.095
00665        C1 = TDOSE * MU / RET
00666        IF(C1 .GT. DIST) C1 = DIST
00667        IF(C1 .LT. 1.0) FLTNHS = 0.0
00668        IF(TEVENT .LT. CL) TEVENT = CL
00669        IF(C1 .LT. 1.0) GO TO 100
00670        C2 = RNQO * FRAC
00671        C3 = SOL * MU * WIDTH * B * EPSAQ / LENGTH
00672        C4 = C2
00673        IF(SOL .NE. 0) C4 = AMIN1(C2,C3)
00674        C5 = 1.0 /SQRT(12.56 * D * MU)
00675        C6 = DCADRE(FLTGRL,1.0,C1,AERR,RERR,ERROR,IER)
00676        FLTNHS = C4 * C5 * C6
00677  C
00678    100 CONTINUE
00679  C
00680        RETURN
00681        END
```

```
00686         FUNCTION EEXP(X)
00687         IF(X .GT.  -100.0) GO TO 100
00688         EEXP = 0.0
00689         RETURN
00690     100 IF(X .LT.  174.08) GO TO 200
00691         EEXP = 4.0E75
00692         RETURN
00693     200 EEXP = EXP(X)
00694         RETURN
00695         END
00696   C
00697   C
00698   C
00699         FUNCTION  DOSE  (CON,DCF1,DCF2,DCF3,MILK,CROPS,BEEF,FISH,NPATH,
00700        1                   U,BRTHRT,UFISH)
00701   C
00702         REAL MILK
00703         COMMON /BLOCK1/ DOSERT(21,13,10,5,2)
00704         COMMON /BLOCK5/ RET(21),XLEACH,B,MU,EPSAQ,WIDTH,HEIGHT,LENGTH,
00705        1                MINEFR,CL,K,TDOSE(13),EPSRP
00706         DIMENSION X(5)
00707         IF(K .EQ. 1  .OR.  K .EQ. 5)  U = BRTHRT
00708         DCF = DCF1
00709         IF(K .EQ. 1) DCF = DCF2
00710         IF(K .EQ. 5) DCF = DCF3
00711         X(1)   =  1.00
00712         X(2)   =  MILK
00713         X(3)   =  CROPS
00714         X(4)   =  BEEF
00715         X(5)   =  FISH
00716         IF(NPATH .EQ. 5) U = UFISH
00717         DOSE   =  0.0
00718   C
00719         DOSE   = U * DCF * CON * X(NPATH)
00720   C
00721         RETURN
00722         END
00723   C
```

```
00724  C
00725  C#########################################################################
00726  C#                                                                       #
00727  C#            MAXI WILL FIND THE INDEX OF THE MAXIMUM CONTRIBUTOR        #
00728  C#                                                                       #
00729  C#########################################################################
00730  C
00731  C
00732        FUNCTION MAXI(A,J)
00733        DIMENSION A(1)
00734        T = 0.0
00735        DO 100 I=1,J
00736        IF(A(I) .LT. T) GO TO 100
00737        T = A(I)
00738        IMAX = I
00739    100 CONTINUE
00740        MAXI = IMAX
00741        RETURN
00742        END
00743  C
00744  C
00745  C
00746  C
```

```
00747  C
00748  C
00749        FUNCTION DRTGRL(S)
00750  C
00751        REAL K1,K2,KPRIME
00752        COMMON /BLOCK3/ A2,A3,T,V
00753        COMMON /BLOCK4/ K1,KPRIME,CVA,CVB,CVC,ALPHA,BETA,AREA
00754        COMMON /BLOCK6/ TEVENT,RNLD(21),SOL(21)
00755        COMMON /BLOCK7/ NNUC,NTIME,FRAC
00756        K2 = K1 - KPRIME * TEVENT
00757        B1 = - RNLD(NNUC) * T
00758        B2 = CVA * K2 * (EEXP( -ALPHA * T)  -  EEXP( -ALPHA * S))/ ALPHA
00759        B3 = CVA * KPRIME  / ALPHA  * ((T - 1)  * EEXP(-ALPHA * T) -
00760       1       ( S - 1) * EEXP( -ALPHA * S))
00761        B4 = CVB * K2 * (EEXP( - BETA * T)  -  EEXP( - BETA * S))/  BETA
00762        B5 = CVB * KPRIME  /  BETA  * ((T - 1)  * EEXP(- BETA * T) -
00763       1       ( S - 1) * EEXP( - BETA * S))
00764        B6 = CVC * (S * (K2 + KPRIME * S / 2) - T * (K2 + KPRIME * T/2))
00765        ARGMU = B1 + (B2 + B3 + B4 + B5 + B6) * AREA / V
00766        X3 = A2 + A3 * S
00767        X4 = X3 + ARGMU
00768        DRTGRL = EEXP(X4)
00769        RETURN
00770        END
00771  C
00772  C
00773  C
00774        FUNCTION FLTGRL(S)
00775  C
00776        COMMON /BLOCK5/ RET(21),XLEACH,B,MU,EPSAQ,WIDTH,HEIGHT,LENGTH,
00777       1                MINEFR,CL,K,TDOSE(13),EPSRP
00778        COMMON /BLOCK6/ TEVENT,RNLD(21),SOL(21)
00779        COMMON /BLOCK7/ NNUC,NTIME,FRAC
00780        COMMON /BLOCK8/ DLIM(5),D,RNQO(21)
00781        REAL LENGTH,MU,MINEFR
00782              IF( K .EQ. 3) GO TO 300
00783              IF(K .EQ. 8   .AND.   SOL(NNUC) .NE. 0) GO TO 300
00784              C1 = B * MU * EPSAQ / (HEIGHT * LENGTH * MINEFR * FRAC *
00785       1                              EPSRP)
00786              C2 = RNLD(NNUC) + C1
00787              C3 = C1 - XLEACH
00788              C4 = TDOSE(NTIME) + TEVENT - S * RET(NNUC) / MU
00789              A1 = C1 / (WIDTH * SQRT(S))
00790              R1 = ALOG(A1)
00791              R1 = R1 - RNLD(NNUC) * S * RET(NNUC) / MU
00792              R2 = EEXP(XLEACH * CL) * XLEACH / C3
00793              R2 = ALOG(R2)
```

```
00794                 R3 = R1 + R2 - C2 * C4
00795                 R4 = R1 + C2 * (TEVENT - C4)
00796                 D1 = R3 + C3 * C4
00797                 D2 = R3 + C3 * TEVENT
00798                 D3 = R4 - RNLD(NNUC) * TEVENT
00799                 D4 = R4 - (XLEACH + RNLD(NNUC)) * TEVENT + XLEACH * CL
00800                 FLTGRL = EEXP(D1) - EEXP(D2) + EEXP(D3) - EEXP(D4)
00801                 GO TO 500
00802    300          CONTINUE
00803                 IF(RNQO(NNUC) .EQ. 0) FLTGRL = 0.0
00804                 IF(RNQO(NNUC) .EQ. 0) GO TO 500
00805  C
00806  C      LEACH LIMITED CALCULATION
00807  C
00808                 AA = FRAC * XLEACH * RNQO(NNUC)
00809                 A2 = ALOG(AA)
00810                 A3 = LENGTH * EPSAQ * B
00811                 A4 = -ALOG(A3)
00812                 A5 = 12.56 * D * MU * S
00813                 A6 = -0.5 * ALOG(A5)
00814                 A7 = -RNLD(NNUC) * (TEVENT + TDOSE(NTIME))
00815                 A8 = -XLEACH * (TDOSE(NTIME) + RET(NNUC) * S / MU)
00816                 A9 = A2 + A4 + A6 + A7 + A8
00817  C
00818  C      SOLUBILITY LIMITED CALCULATION
00819  C
00820                 IF(SOL(NNUC) .EQ. 0) GO TO 400
00821                 B1 = MU * EPSAQ * WIDTH * SOL(NNUC)
00822                 B2 = ALOG(B1)
00823                 B3 = -RNLD(NNUC) * RET(NNUC) * S / MU
00824                 B4 = B2 + B3 + A4 + A6
00825                 A9 = AMIN1(A9,B4)
00826    400          FLTGRL = EEXP(A9)
00827  C
00828  C
00829    500          CONTINUE
00830                 RETURN
00831                 END
00832  C
```

```
00833  C
00834  C
00835        SUBROUTINE OUTPUT(NPATH,J,T,R1,R2,R3,R4,XMU,LT,LD,ID)
00836        COMMON /BLOCK2/ REM(13,10,5,2),  PCT(13,10,5,2),  NAME(13,10,5,2),
00837       1                DIST(10)
00838        COMMON /BLOCK5/ RET(21),XLEACH,B,MU,EPSAQ,WIDTH,HEIGHT,LENGTH,
00839       1                MINEFR,CL,K,TDOSE(13),EPSRP
00840        REAL *8 R1,NAME,DATE,TIMES,NONE
00841        REAL *4 R2,R3,R4
00842  C
00843  C
00844  C#############################################################################
00845  C#                                                                           #
00846  C#      CTIME WILL RETURN THE DATE AND THE TIME OF DAY THE JOB               #
00847  C#                            IS RUN.                                        #
00848  C#                                                                           #
00849  C#############################################################################
00850  C
00851  C
00852        CALL CTIME(DATE,TIMES)
00853  C
00854  C
```

```
00855         DO 3000 NORGAN=1,J
00856         IF(K .EQ. 4) GO TO 750
00857         IF(K .EQ. 1  .OR. K .EQ. 5) GO TO 2000
00858         WRITE(6,100) DATE,TIMES,R1,R2,R3,R4,T,NORGAN
00859         WRITE(6,200)
00860         WRITE(6,300) (DIST(NN),NN=1,LD)
00861         DO 700 JJ=1,LT
00862         WRITE(6,400) (REM(JJ,II,1,NORGAN),II=1,LD)
00863         WRITE(6,500) TDOSE(JJ),(NAME(JJ,II,1,NORGAN),II=1,LD)
00864         WRITE(6,600) (PCT(JJ,II,1,NORGAN),II=1,LD)
00865     700 CONTINUE
00866   C
00867   C
00868         NP = 1
00869         IF(K.EQ.2 .AND. ID.NE.1  .OR.  K.EQ.6 .AND. ID.NE.1) CALL
00870        1ARECLC(DATE,TIMES,NORGAN,R1,R2,R3,R4,T,XMU,NP,NTIME)
00871   C
00872   C
00873     750 CONTINUE
00874         IF(NPATH .GT. 1) GO TO 800
00875         GO TO 3000
00876     800 CONTINUE
00877         WRITE(6,900) DATE,TIMES,R1,R2,R3,R4,T,NORGAN
00878         WRITE(6,200)
00879         WRITE(6,300) (DIST(NN),NN=1,LD)
00880         DO 1000 JJ=1,LT
00881         WRITE(6,400) (REM(JJ,II,2,NORGAN),II=1,LD)
00882         WRITE(6,500) TDOSE(JJ),(NAME(JJ,II,2,NORGAN),II=1,LD)
00883         WRITE(6,600) (PCT(JJ,II,2,NORGAN),II=1,LD)
00884    1000 CONTINUE
00885   C
00886   C
00887         NP = 2
00888         IF(K.EQ.2 .AND. ID.NE.1  .OR.  K.EQ.6 .AND. ID.NE.1) CALL
00889        1ARECLC(DATE,TIMES,NORGAN,R1,R2,R3,R4,T,XMU,NP,NTIME)
00890   C
00891   C
00892         IF(NPATH .GT. 2) GO TO 1050
00893         GO TO 3000
00894    1050 CONTINUE
00895         WRITE(6,1100) DATE,TIMES,R1,R2,R3,R4,T,NORGAN
00896         WRITE(6,200)
00897         WRITE(6,300) (DIST(NN),NN=1,LD)
00898         DO 1200 JJ=1,LT
00899         WRITE(6,400) (REM(JJ,II,3,NORGAN),II=1,LD)
00900         WRITE(6,500) TDOSE(JJ),(NAME(JJ,II,3,NORGAN),II=1,LD)
00901         WRITE(6,600) (PCT(JJ,II,3,NORGAN),II=1,LD)
00902    1200 CONTINUE
```

```
00903  C
00904  C
00905        NP = 3
00906        IF(K.EQ.2 .AND. ID.NE.1  .OR.  K.EQ.6 .AND. ID.NE.1) CALL
00907       1ARECLC(DATE,TIMES,NORGAN,R1,R2,R3,R4,T,XMU,NP,NTIME)
00908  C
00909  C
00910        IF(NPATH .GT. 3) GO TO 1400
00911        GO TO 3000
00912   1400 CONTINUE
00913        WRITE(6,1300) DATE,TIMES,R1,R2,R3,R4,T,NORGAN
00914        WRITE(6,200)
00915        WRITE(6,300) (DIST(NN),NN=1,LD)
00916        DO 1450 JJ=1,LT
00917        WRITE(6,400) (REM(JJ,II,4,NORGAN),II=1,LD)
00918        WRITE(6,500) TDOSE(JJ),(NAME(JJ,II,4,NORGAN),II=1,LD)
00919        WRITE(6,600) (PCT(JJ,II,4,NORGAN),II=1,LD)
00920   1450 CONTINUE
00921  C
00922  C
00923        NP = 4
00924        IF(K.EQ.2 .AND. ID.NE.1  .OR.  K.EQ.6 .AND. ID.NE.1) CALL
00925       1ARECLC(DATE,TIMES,NORGAN,R1,R2,R3,R4,T,XMU,NP,NTIME)
00926  C
00927  C
00928        IF(NPATH .EQ. 5) GO TO 1475
00929        GO TO 3000
00930   1475 IF(K .NE. 4) GO TO 3000
00931        WRITE(6,1500) DATE,TIMES,R1,R2,R3,R4,T,NORGAN
00932        WRITE(6,200)
00933        WRITE(6,300) (DIST(NN),NN=1,LD)
00934        DO 1600 JJ=1,LT
00935        WRITE(6,400) (REM(JJ,II,5,NORGAN),II=1,LD)
00936        WRITE(6,500) TDOSE(JJ),(NAME(JJ,II,5,NORGAN),II=1,LD)
00937        WRITE(6,600) (PCT(JJ,II,5,NORGAN),II=1,LD)
00938   1600 CONTINUE
00939   2000 CONTINUE
00940        WRITE(6,1700) DATE,TIMES,R1,R2,R3,R4,T,NORGAN
00941        WRITE(6,200)
00942        WRITE(6,300) (DIST(NN),NN=1,LD)
00943        DO 2100 JJ=1,LT
00944        WRITE(6,400) (REM(JJ,II,1,NORGAN),II=1,LD)
00945        WRITE(6,500) TDOSE(JJ),(NAME(JJ,II,1,NORGAN),II=1,LD)
00946        WRITE(6,600) (PCT(JJ,II,1,NORGAN),II=1,LD)
00947   2100 CONTINUE
```

```
00948  C
00949  C
00950        IF(K.EQ.1 .AND. ID.NE.1  .OR.  K.EQ.5 .AND. ID.NE.1) CALL LSAREA
00951       1                    (DATE,TIMES,NORGAN,R1,R2,R3,R4,T,NTIME)
00952  C
00953  C
00954   3000 CONTINUE
00955    200 FORMAT(1H0,58X,'DISTANCE  (METERS)')
00956    300 FORMAT(1H0,'TIME(YRS)',3X,10(4X,F7.2,1X))
00957    400 FORMAT(1H0,12X,10(3X,1PE9.2))
00958    500 FORMAT(1X,1PE8.2,8X,A8,9(4X,A8))
00959    600 FORMAT(1H ,13X,F7.1,'%',9(4X,F7.1,'%'))
00960    100 FORMAT(1H1,A8,4X,A8,87X,A8,3A4,//,30X,'MAXIMUM INDIVIDUAL DOSES(RE
00961       1M/YR) AQUIFERS',5X,'EVENT TIME:',F6.1,' YEARS',25X,'(',I1,')')
00962    900 FORMAT(1H1,A8,4X,A8,87X,A8,3A4,//,30X,'MAXIMUM INDIVIDUAL DOSES(RE
00963       1M/YR)   MILK  ',5X,'EVENT TIME:',F6.1,' YEARS',25X,'(',I1,')')
00964   1100 FORMAT(1H1,A8,4X,A8,87X,A8,3A4,//,30X,'MAXIMUM INDIVIDUAL DOSES(RE
00965       1M/YR)   CROPS ',5X,'EVENT TIME:',F6.1,' YEARS',25X,'(',I1,')')
00966   1300 FORMAT(1H1,A8,4X,A8,87X,A8,3A4,//,30X,'MAXIMUM INDIVIDUAL DOSES(RE
00967       1M/YR)   BEEF  ',5X,'EVENT TIME:',F6.1,' YEARS',25X,'(',I1,')')
00968   1500 FORMAT(1H1,A8,4X,A8,87X,A8,3A4,//,30X,'MAXIMUM INDIVIDUAL DOSES(RE
00969       1M/YR)   FISH  ',5X,'EVENT TIME:',F6.1,' YEARS',25X,'(',I1,')')
00970   1700 FORMAT(1H1,A8,4X,A8,87X,A8,3A4,//,30X,'MAXIMUM INDIVIDUAL DOSES(RE
00971       1M/YR) INHALATION',3X,'EVENT TIME:',F6.1,' YEARS',25X,'(',I1,')')
00972        RETURN
00973        END
00974  C
00975  C
00976  C
```

```
00977  C
00978  C
00979        SUBROUTINE INIT(NRN30,IPATH,IORGAN)
00980        COMMON /BLOCK1/ DOSERT(21,13,10,5,2)
00981        COMMON /BLOCK2/ REM(13,10,5,2),  PCT(13,10,5,2),  NAME(13,10,5,2),
00982       1                              DIST(10)
00983        DO 100 M=1,IORGAN
00984        REAL *8 NAME
00985         DO 100 L=1,IPATH
00986          DO 100 K=1,10
00987           DO 100 J=1,13
00988                REM(J,K,L,M) = 0.0
00989                PCT(J,K,L,M) = 0.0
00990            DO 100 I=1,NRN30
00991                DOSERT(I,J,K,L,M) = 0.0
00992    100 CONTINUE
00993        RETURN
00994        END
00995  C
00996  C
00997  C
00998  C
00999        SUBROUTINE UERTST(IER,X)
01000        IF (IER .GT. 66) WRITE(6,100) IER
01001    100 FORMAT(1H ,'IER = ',I3,'(ANSWERS MAY NOT BE WITHIN THE SPECIFIED
01002       1ERROR RANGE DUE TO AN ILL BEHAVED FUNCTION)')
01003        RETURN
01004        END
01005  C
01006  C
```

```
01007  C
01008        SUBROUTINE ARECLC(DATE,TIMES,L,R1,R2,R3,R4,T,XMU,NP,NT)
01009        COMMON /BLOCK2/ REM(13,10,5,2),  PCT(13,10,5,2),  NAME(13,10,5,2),
01010       1                DIST(10)
01011        COMMON /BLOCK5/ RET(21),XLEACH,B,MU,EPSAQ,WIDTH,HEIGHT,LENGTH,
01012       1                MINEFR,CL,K,TDOSE(13),EPSRP
01013        COMMON /BLOCK8/ DLIM(5),D,RNOO(21)
01014        REAL *4 R2,R3,R4
01015        REAL *8 R1,DATE,TIMES,NAME
01016        DIMENSION HT(10),AREADO(5)
01017        IF(DLIM(1) .EQ. 0.0) GO TO 1600
01018        WRITE(6,1000) DATE,TIMES,R1,R2,R3,R4,T,L,DLIM(1),DLIM(2),DLIM(2),
01019       1        DLIM(3),DLIM(3),DLIM(4),DLIM(4),DLIM(5),(DLIM(JJ),JJ=1,5)
01020    1000 FORMAT(1H1,A8,2X,A8,75X,A8,3A4,//,32X,'EXTENT OF CONTAMINATION',
01021       110X,'EVENT TIME :',F7.1,10X,'ORGAN:',I1,//,53X,'AREA  (SQUARE METE
01022       1RS)          ',/,3X,'TIME',24X,'INCREMENTAL AREAS',45X,'CUMULATIVE
01023       1AREAS',/,2X,'(YEARS)',T14,G9.4,T19,'-',G9.4,T27,G9.4,T32,'-',G9.4,
01024       1T40,G9.4,T45,'-',G9.4,T53,G9.4,T58,'-',G9.4,T74,G9.4,T80,'+',T86,
01025       1G9.4,T92,'+',T98,G9.4,T104,'+',T110,G9.4,T116,'+',T122,G9.4,T127,
01026       1'+',/)
01027  C
01028  C****   N     TIME LOOP
01029  C
01030        DO 1600 N=1,NT
01031  C
01032  C****         INITIALIZE AREADO ARRAY
01033  C
01034        DO 1501 I=1,5
01035    1501 AREADO(I)=0.0
01036  C
01037  C****   I     FIVE AREAS LOOP
01038  C
01039             DO 1500 I=1,5
01040  C
01041  C****   J     DISTANCE LOOP
01042  C
01043             DO 1400 J=1,10
01044             IF(REM(N,J,NP,L) .EQ. 0) AR = 0.0
01045             IF(REM(N,J,NP,L) .EQ. 0) GO TO 1400
01046             FRACT = DLIM(I) / REM(N,J,NP,L)
01047             IF (REM(N,J,NP,L) .LT. DLIM(I))  FRACT=1.0
01048  C
01049  C****         CALCULATE THE EXTENT OF THE DOSE AWAY FROM THE CENTER LINE
01050  C
01051             AA=ALOG(FRACT)
01052             ARG = -4.0 * D / XMU * DIST(J) * AA
01053             HT(J)=SQRT(ARG)
01054             IF (J.GT.1) GO TO 300
01055  C
```

```
C****     COMPUTE THE AREA UNDER THE PARABOLA FROM ORIGON TO FIRST POINT
C
              C1=-ALOG(FRACT)
              IF (C1 .LT. 0.0)  GO  TO  250
              AR=6.53*SQRT(C1)*DIST(J)**1.5
              GO TO 1400
  250         AR=0.0
              GO TO 1400
  300         YABS=ABS(HT(J-1)-HT(J))
              HITMIN=AMIN1(HT(J-1),HT(J))
C
C****         COMPUTES AREAS BETWEEN SUBSEQUENT POINTS USING TRAPOZOIDS
C
              AR=2.0*(DIST(J)-DIST(J-1))*(HITMIN+.5*YABS)
C
C****         COMPUTE THE TOTAL AREA FROM CENTERLINE TO DLIM(I)
C
 1400                AREADO(I)=AR+AREADO(I)
 1500 CONTINUE
C
C****         COMPUTE AREAS BETWEEN THE VARIOUS DLIM(I)
C
      AAREA=AREADO(1)-AREADO(2)
      BAREA=AREADO(2)-AREADO(3)
      CAREA=AREADO(3)-AREADO(4)
      DAREA=AREADO(4)-AREADO(5)
      WRITE(6,1550) TDOSE(N),AAREA,BAREA,CAREA,DAREA,
     1              (AREADO(I),I=1,5)
 1550 FORMAT(1H ,1PE9.2,4X,4(1PE9.2,4X),6X,5(1PE9.2,3X))
 1600 CONTINUE
      RETURN
      END
C
C
      SUBROUTINE LSAREA(DATE,TIMES,L,R1,R2,R3,R4,T,NT)
      COMMON /BLOCK2/ REM(13,10,5,2),  PCT(13,10,5,2),  NAME(13,10,5,2),
     1                DIST(10)
      COMMON /BLOCK5/ RET(21),XLEACH,B,MU,EPSAQ,WIDTH,HEIGHT,LENGTH,
     1                MINEFR,CL,K,TDOSE(13),EPSRP
      COMMON /BLOCK8/ DLIM(5),D,RNQO(21)
      REAL *4 R2,R3,R4
      REAL *8 R1,DATE,TIMES,NAME
      DIMENSION AREALS(5)
```

```
01099        IF(DLIM(1) .EQ. 0.0) GO TO 2000
01100        WRITE(6,1000) DATE,TIMES,R1,R2,R3,R4,T,L,DLIM(1),DLIM(2),DLIM(2),
01101       1        DLIM(3),DLIM(3),DLIM(4),DLIM(4),DLIM(5),(DLIM(JJ),JJ=1,5)
01102  C
01103  C
01104  C     THIS SUBROUTINE CALCULATES CONTAMINATED AREAS OF LAND SURFACE
01105  C     DUE TO A DRILLING RELEASE TO THE SURFACE. SIMPLE INTERPOLATION
01106  C     IS USED TO DETERMIND THE MAXIMUM EXTENT ( DISTANCE FROM THE
01107  C     SOURCE ) OF CONTAMINATION ABOVE A GIVEN LEVEL (DLIM)
01108  C
01109  C
01110  C*****TIME LOOP
01111  C
01112        DO 500 N = 1,NT
01113           IF(REM(N,1,1,L) .LT. DLIM(1)  .AND.  N .GT. 1) WRITE(6,1001)
01114       1        DLIM(1),TDOSE(N-1)
01115           IF(REM(N,1,1,L) .LT. DLIM(1)  .AND.  N .EQ. 1) WRITE(6,1001)
01116       2        DLIM(1),TDOSE(1)
01117           IF( REM(N,1,1,L) .LT. DLIM(1)) GO TO 2000
01118  C
01119  C**** THE PRECEEDING STATEMENT ALLOWS US TO JUMP OUT OF THE SUBROUTINE
01120  C     IF THERE ARE NO AREAS TO CALCULATE. IT IS CORRECT SINCE THE DOSES
01121  C*****ALWAYS DECREASE WITH TIME AND DISTANCE FOR A LAND SURFACE RELEASE.
01122  C
01123  C
01124  C*****INITIALIZE AREA ARRAY
01125  C
01126        DO 400 I=1,5
01127    400 AREALS(I) = 0.0
01128  C
01129  C*****FIVE AREAS LOOP
01130  C
01131        DO 300 I=1,5
01132  C
01133  C*****DISTANCE LOOP
01134  C
01135           IF(REM(N,1,1,L) .LT. DLIM(I)) GO TO 350
01136           DO 200 KK=1,10
01137           IF(KK .EQ. 10) GO TO 100
01138           IF (REM(N,KK,1,L) .GE. DLIM(I)) GO TO 200
01139  C
01140  C     THE PRECEEDING STATEMENT FINDS THE DISTANCE AT WHICH THE DOSE
01141  C     FALLS BELOW DLIM. UNTIL THAT POINT IT SKIPS THE CALCULATION
01142  C     OF AREA BY JUMPING TO THE END OF THE LOOP
01143  C
01144  C
01145  C
01146  C     THE GO TO 100 STATEMENT CALCULATES AREAS EVEN IF THE FINAL
01147  C     DISTANCE IS REACHED WITHOUT DROPPING BELOW DLIM(1)
```

```
01148  C
01149  C
01150     100 A1 = REM(N,KK-1,1,L) - DLIM(I)
01151         A2 = DIST(KK) - DIST(KK-1)
01152         A3 = REM(N,KK-1,1,L) - REM(N,KK,1,L)
01153         AREALS(I) = 3.14159 * (DIST(KK-1) + (A1 * A2) / A3) ** 2
01154         GO TO 300
01155     200 CONTINUE
01156     300 CONTINUE
01157  C
01158  C      COMPUTE THE AREAS BETWEEN THE VARIOUS DLIM(I)
01159  C
01160     350 AAREA = AREALS(1) - AREALS(2)
01161         BAREA = AREALS(2) - AREALS(3)
01162         CAREA = AREALS(3) - AREALS(4)
01163         DAREA = AREALS(4) - AREALS(5)
01164  C
01165  C
01166  C
01167         WRITE(6,800) TDOSE(N),AAREA,BAREA,CAREA,DAREA,
01168        1             (AREALS(J),J=1,5)
01169     500 CONTINUE
01170     800 FORMAT(1H ,1PE9.2,4X,4(1PE9.2,4X),6X,5(1PE9.2,3X))
01171    1000 FORMAT(1H1,A8,2X,A8,75X,A8,3A4,//,32X,'EXTENT OF CONTAMINATION',
01172        110X,'EVENT TIME :',F7.1,10X,'ORGAN:',I1,//,53X,'AREA  (SQUARE METE
01173        1RS)          ',/,3X,'TIME',24X,'INCREMENTAL AREAS',45X,'CUMULATIVE
01174        1AREAS',/,2X,'(YEARS)',T14,G9.4,T19,'-',G9.4,T27,G9.4,T32,'-',G9.4,
01175        1T40,G9.4,T45,'-',G9.4,T53,G9.4,T58,'-',G9.4,T74,G9.4,T80,'+',T86,
01176        1G9.4,T92,'+',T98,G9.4,T104,'+',T110,G9.4,T116,'+',T122,G9.4,T127,
01177        1'+',/)
01178    1001 FORMAT(1H ,15X,'THERE WERE NO CONTAMINATED AREAS FOR DOSES ABOVE',
01179        1F4.1,'REM AFTER ',1PE8.2,' YEARS')
01180    2000 RETURN
01181         END
```

APPENDIX B

SAMPLE PROBLEM

Appendix B
Sample Problem

Our sample problem is a hypothetical drilling event occurring 1000 years after the repository is sealed. Fifteen percent of one canister in an insoluble form is assumed to be transported to the land surface by the drill bit. The nuclides are assumed to be dispersed in the atmosphere. The dose has been calculated primarily for the lungs from inhaling the contaminated air near the drilling event.

Table B-1 is the sample input deck as it is read by the computer. Table B-2 is an echo check of the dataset.

Table B-3 is the dose table. The distances from the drilling site are indicated in the column headings across the top of the page and the number of years after the event are listed down the side of the page. The first entry in the table reads:

	20.00
	1.12E+01
1.00E+01	AM-241
	54.2%

The dose to an individual occurs 10 years after the event and 20 meters from the land surface release point. An individual remaining there for a year receives a dose of 11.2 rem. The major lung dose contributor is Americium-241 which contributes 54.2 percent of the 11.2 rem dose. Individuals remaining there for a fraction of year receive a linearly dependent dose. For example, a person receiving a 1-month exposure receives approximately one-twelfth of the total dose or .93 rem.

Table B-4 indicates the areas contaminated by the event in square meters. The areas were calculated by assuming that the contaminated area isodose boundaries are parabolic for aquifers and circular for air. Cumulative areas are also calculated. For example, from Table B-4 we discover for our sample problem that about 10^5 square meters are contaminated above .5 rem for about 100 years.

Cumulative areas are expressed as (b, ∞), (c, ∞), (d, ∞)
Incremental areas are expressed as (b, c), (c, d), (d, e)...

Table 8-1. Sample Problem. Input Deck, MAXDOSE-EPA

```
1.              1       1       7       1
2.
3.          THIS DATASET WILL RUN A RELEASE TO THE LAND SURFACE
4.          RESULTING FROM DRILLING INTO THE WASTE. THERE WILL
5.          BE 2 TABLES OF OUTPUT ONE FOR DOSES TO THE LUNGS
6.          AND THE SECOND,LAND SURFACE AREAS CONTAMINATED.    PGM = IMSL.MAXDOSE
7.          BARRY L. SERINI        03/11/81   DATASET=MAXDOSE.DATA1   JCL=IMSL.GO
8.
9.     10     20.     50.    100.    200.    500.    750.   1000.
10.    11  1.5E3    2.E3    4.E3
11.    20     .5      5.     50.    500.   5.0E3
12.    30    458.  4.02E8  5.0E-4  5.0E-6    100.     160.          AM-241
13.    31  3.2E7  2.35E9  3.13E8  9.43E8   6.4E6   8.5E6           AM-241
14.    32 1.0E-3     1.2    .014    25.0                           AM-241
15.    30 3.79E5  1.74E5   5.E-4   5.E-6    100.  4.0E-6           PU-242
16.    31   2.9E7  2.17E9  2.8E8  8.69E8  1.80E5   2.4E5          PU-242
17.    32    .001     1.2    .004     3.5                         PU-242
18.    30  6760.0  4.89E7  5.E-04  5.0E-6    100.  2.2E-4          PU-240
19.    31  3.1E+7  2.28E9  2.95E8  9.13E8  1.9E+5  2.5E+5          PU-240
20.    32    .001     1.2    .004     3.5                         PU-240
21.    30 2.39E4  3.31E7  5.E-04   5.E-6   100.0  6.0E-5          PU-239
22.    31   3.E7  2.25E9  2.94E8  9.12E8  1.9E+5  2.5E+5          PU-239
23.    32    .001     1.2    .004     3.5                         PU-239
24.    30     89.  2.19E8  5.0E-4  5.0E-6    100.                 PU-238
25.    31  3.2E+7  2.03E9  3.09E8  7.91E8  1.7E5   2.2E+5          PU-238
26.    32    .001     1.2    .004     3.5                         PU-238
27.    30 2.14E6  1.21E5   5.E-2   5.E-4    100.  7.2E-7          NP-237
28.    31   3.E7  2.4E+9  2.9E+8  9.04E4   6.2E6  8.2E+6          NP-237
29.    32    .001     1.2    .014     10.                         NP-237
30.    30    28.8     6.E9  2.3E-3  5.0E-4      1.                 SR -90
31.    31 4.92E4     3.26  8.54E6  9.31E5   4.3E5   7.8E4          SR -90
32.    32    .295     1.2     .04     30.                         SR -90
33.    30  7650.  1.72E6   5.E-4   5.E-6    100.     10.          AM-243
34.    31   3.1E7  3.88E9  3.03E8  1.56E9   6.4E6   8.3E6          AM-243
35.    32    .001     1.2    .012     25.                         AM-243
36.    30  5730.  5.62E4      .5    .005      1.                  C - 14
37.    31    6.18    24.20    6.18    24.2   3400.    1500.       C - 14
38.    32      9.     1.2     15.    4600.                        C - 14
39.    30  9.5E5  1.87E5   5.0E-4  5.0E-6    100.  2.0E-6          ZR -93
40.    31 3.08E4  6.98E3   5.85E4  7.16E3    300.  1.3E+4          ZR -93
41.    32  .0020    1.15    .3540     3.3                         ZR -93
42.    30  2.1E5  1.43E6      2.6    .026      1.  2.0E-5          TC -99
43.    31 5.22E4  9.46E3  5.22E4  9.46E3   320.0  1.4E+4          TC -99
44.    32     9.     1.2    .070    15.0                         TC -99
45.    30 1.7E+7  3.77E3     .12  .00120      1.                  I -129
46.    31   788.   5.E+6    788.  5.0E+6    940.  7.8E+6          I -129
47.    32    3.6     1.2    2.83     15.                         I -129
48.    30   3.E+6  2.23E4   5.E-3   5.E-5      1.                CS-135
49.    31   640.   7480.   640.0  7480.0  1.1E4   1.1E4          CS-135
50.    32   2.08     1.2     .26   2000.                        CS-135
51.    30     30.  8.64E9  5.E-03   5.E-4      1.                CS-137
52.    31 1.62E4  5.23E4  1.62E4  5.23E4   7.4E4   7.9E4          CS-137
53.    32   2.08     1.2     .26   2000.                        CS-137
54.    30 1.0E+5   5.6E4  4.5E-3  4.5E-5     10.  3.0E-2          SN-126
55.    31 1.27E6  1.58E5  1.27E6  1.58E5  8.57E4  1.18E5          SN-126
56.    32   5.66     1.43    .899    3000.                        SN-126
57.    40  4.0E3   2.0E3     5.0      .1  1.0E-4    100.     .12
58.    41 1.78E7     .25   8.0E3    .603    .021
59.    50    30.     12.6     2.1     .15     .20    31.5     0.0
60.    60 1.6E-3  3.1E-4    .132    .103      .1
61.    70 4.29E-6                                               LAND SURFACE RELEASE
62.    80   1000.     10.     20.     50.    100.    200.    500.
63.    81   1000.   2000.   3000.   1.E4    2.E4    5.E4   1.E5
64.    99
```

Table B-2. Sample Problem. Echo Check of the Dataset, MAXDOSE-EPA

```
     1        1        7        1        2

THIS DATASET WILL RUN A RELEASE TO THE LAND SURFACE
RESULTING FROM DRILLING INTO THE WASTE. THERE WILL
BE 2 TABLES OF OUTPUT ONE FOR DOSES TO THE LUNGS
AND THE SECOND,LAND SURFACE AREAS CONTAMINATED.     PGM = IMSL.MAXDOSE
BARRY L. SERINI          03/11/81   DATASET=MAXDOSE.DATA1   JCL=IMSL.GO

10      2.00E+01  5.00E+01  1.00E+02  2.00E+02  5.00E+02  7.50E+02  1.00E+03
11      1.50E+03  2.00E+03  4.00E+03  0.0       0.0       0.0       0.0
20      5.00E-01  5.00E+00  5.00E+01  5.00E+02  5.00E+03  0.0       0.0
30      4.58E+02  4.02E+08  5.00E-04  5.00E-06  1.00E+02  1.60E+02  0.0       AM-241
31      3.20E+07  2.35E+09  3.13E+08  9.43E+08  6.40E+06  8.50E+06  0.0       AM-241
32      1.00E-03  1.20E+00  1.40E-02  2.50E+01  0.0       0.0       0.0       AM-241
30      3.79E+05  1.74E+05  5.00E-04  5.00E-06  1.00E+02  4.00E-06  0.0       PU-242
31      2.90E+07  2.17E+09  2.80E+08  8.69E+08  1.80E+05  2.40E+05  0.0       PU-242
32      1.00E-03  1.20E+00  4.00E-03  3.50E+00  0.0       0.0       0.0       PU-242
30      6.76E+03  4.89E+07  5.00E-04  5.00E-06  1.00E+02  2.20E-04  0.0       PU-240
31      3.10E+07  2.28E+09  2.95E+08  9.13E+08  1.90E+05  2.30E+05  0.0       PU-240
32      1.00E-03  1.20E+00  4.00E-03  3.50E+00  0.0       0.0       0.0       PU-240
30      2.39E+04  3.31E+07  5.00E-04  5.00E-06  1.00E+02  6.00E-05  0.0       PU-239
31      3.00E+07  2.28E+09  2.94E+08  9.12E+08  1.90E+05  2.50E+05  0.0       PU-239
32      1.00E-03  1.20E+00  4.00E-03  3.50E+00  0.0       0.0       0.0       PU-239
30      8.90E+01  2.19E+08  5.00E-04  5.00E-06  1.00E+02  0.0       0.0       PU-238
31      3.20E+07  2.03E+09  3.09E+08  7.91E+08  1.70E+05  2.20E+05  0.0       PU-238
32      1.00E-03  1.20E+00  4.00E-03  3.50E+00  0.0       0.0       0.0       PU-238
30      2.14E+06  1.21E+05  5.00E-02  5.00E-04  1.00E+02  7.20E-07  0.0       NP-237
31      3.00E+07  2.40E+09  2.90E+08  9.04E+04  6.20E+06  8.20E+06  0.0       NP-237
32      1.00E-03  1.20E+00  1.40E-02  1.00E+01  0.0       0.0       0.0       NP-237
30      2.88E+01  6.00E+09  2.30E-03  5.00E-04  1.00E+00  0.0       0.0       SR -90
31      4.92E+04  3.00E+06  8.34E+06  9.31E+05  4.30E+05  7.80E+04  0.0       SR -90
32      2.95E-01  1.20E+00  4.00E-02  3.00E+01  0.0       0.0       0.0       SR -90
30      7.65E+03  1.77E+06  5.00E-04  5.00E-06  1.00E+02  1.00E+01  0.0       AM-243
31      3.10E+07  3.88E+09  3.03E+08  1.56E+09  6.40E+06  8.50E+06  0.0       AM-243
32      1.00E-03  1.20E+00  1.20E-02  2.50E+01  0.0       0.0       0.0       AM-243
30      5.73E+03  5.62E+04  5.00E-01  5.00E-03  1.00E+00  0.0       0.0       C - 14
31      6.18E+00  2.42E+01  6.18E+00  2.42E+01  3.40E+03  1.50E+03  0.0       C - 14
32      9.00E+00  1.20E+00  1.50E+01  4.60E+03  0.0       0.0       0.0       C - 14
30      9.50E+05  1.87E+05  5.00E-04  5.00E-06  1.00E+02  2.00E-06  0.0       ZR -93
31      3.08E+04  6.98E+03  5.85E+04  7.16E+03  3.00E+02  1.30E+04  0.0       ZR -93
32      2.00E-03  1.15E+00  3.34E-01  3.30E+00  0.0       0.0       0.0       ZR -93
30      2.10E+05  1.43E+06  2.60E+00  2.60E-02  1.00E+00  2.00E-05  0.0       TC -99
31      5.22E+04  9.46E+03  5.22E+04  9.46E+03  3.20E+02  1.40E+04  0.0       TC -99
32      9.00E+00  1.20E+00  7.00E-02  1.50E+01  0.0       0.0       0.0       TC -99
30      1.70E+07  3.77E+03  1.20E-01  1.20E-03  1.00E+00  0.0       0.0       I -129
31      7.88E+02  5.00E+06  7.88E+02  5.00E+06  9.40E+02  7.80E+06  0.0       I -129
32      3.60E+00  1.20E-00  2.83E+00  1.50E+01  0.0       0.0       0.0       I -129
30      3.00E+06  2.23E+04  5.00E-03  5.00E-05  1.00E+00  0.0       0.0       CS-135
31      6.40E+02  7.48E+03  6.40E+02  7.48E+03  1.10E+04  1.10E+04  0.0       CS-135
32      2.08E+00  1.20E+00  2.60E-01  2.00E+03  0.0       0.0       0.0       CS-135
30      3.00E+01  8.64E+09  5.00E-03  5.00E-04  1.00E+00  0.0       0.0       CS-137
31      1.62E+04  5.23E+04  1.62E+04  5.23E+04  7.40E+04  7.90E+04  0.0       CS-137
32      2.08E+00  1.20E+00  2.60E-01  2.00E+03  0.0       0.0       0.0       CS-137
30      1.00E+05  5.60E+04  4.50E-03  4.50E-05  1.00E+01  3.00E-02  0.0       SN-126
31      1.27E+06  1.58E+05  1.27E+06  1.58E+05  8.57E+04  1.18E+05  0.0       SN-126
32      5.66E+00  1.43E+00  8.99E-01  3.00E+03  0.0       0.0       0.0       SN-126
40      4.00E+03  2.00E+03  5.00E+00  1.00E-01  1.00E-04  1.00E+02  1.20E-01
41      1.78E+07  2.50E-01  8.00E+03  6.03E-01  2.10E-02  0.0       0.0
50      3.00E+01  1.26E+01  2.10E+00  1.50E-01  2.00E-01  3.15E+01  0.0
60      1.60E-03  3.10E-04  1.32E-01  1.03E-01  1.00E-01  0.0       0.0
70      4.29E-06  0.0       0.0       0.0       0.0       0.0       0.0       LAND SURFACE RELEASE
80      1.00E+03  1.00E+01  2.00E+01  5.00E+01  1.00E+02  2.00E+02  5.00E+02
81      1.00E+03  2.00E+03  5.00E+03  1.00E+04  2.00E+04  5.00E+04  1.00E+05
99      0.0       0.0       0.0       0.0       0.0       0.0       0.0
```

Table B-3. Sample Problem. Maximum Individual Doses

04/08/81 07:55:30 LAND SURFACE RELEASE

MAXIMUM INDIVIDUAL DOSES(REM/YR) INHALATION EVENT TIME:1000.0 YEARS (1)

TIME(YRS)	DISTANCE (METERS) 20.00	50.00	100.00	200.00	500.00	750.00	1000.00	1500.00	2000.00	4000.00
1.00E+01	1.12E+01 AM-241 54.2%	2.96E+00 AM-241 54.2%	1.07E+00 AM-241 54.2%	3.84E-01 AM-241 54.2%	9.61E-02 AM-241 54.2%	5.13E-02 AM-241 54.2%	3.26E-02 AM-241 54.2%	1.70E-02 AM-241 54.2%	1.06E-02 AM-241 54.2%	3.22E-03 AM-241 54.2%
2.00E+01	1.11E+01 AM-241 53.9%	2.92E+00 AM-241 53.9%	1.06E+00 AM-241 53.9%	3.79E-01 AM-241 53.9%	9.48E-02 AM-241 53.9%	5.06E-02 AM-241 53.9%	3.22E-02 AM-241 53.9%	1.68E-02 AM-241 53.9%	1.04E-02 AM-241 53.9%	3.18E-03 AM-241 53.9%
5.00E+01	1.06E+01 AM-241 52.8%	2.81E+00 AM-241 52.8%	1.02E+00 AM-241 52.8%	3.64E-01 AM-241 52.8%	9.10E-02 AM-241 52.8%	4.86E-02 AM-241 52.8%	3.09E-02 AM-241 52.8%	1.61E-02 AM-241 52.8%	1.00E-02 AM-241 52.8%	3.05E-03 AM-241 52.8%
1.00E+02	9.94E+00 AM-241 51.0%	2.63E+00 AM-241 51.0%	9.51E-01 AM-241 51.0%	3.41E-01 AM-241 51.0%	8.52E-02 AM-241 51.0%	4.55E-02 AM-241 51.0%	2.89E-02 AM-241 51.0%	1.51E-02 AM-241 51.0%	9.38E-03 AM-241 51.0%	2.86E-03 AM-241 51.0%
2.00E+02	8.74E+00 AM-241 47.4%	2.31E+00 AM-241 47.4%	8.36E-01 AM-241 47.4%	2.99E-01 AM-241 47.4%	7.49E-02 AM-241 47.4%	4.00E-02 AM-241 47.4%	2.54E-02 AM-241 47.4%	1.32E-02 AM-241 47.4%	8.25E-03 AM-241 47.4%	2.51E-03 AM-241 47.4%
5.00E+02	6.12E+00 AM-241 36.9%	1.62E+00 AM-241 36.9%	5.86E-01 AM-241 36.9%	2.10E-01 AM-241 36.9%	5.25E-02 AM-241 36.9%	2.80E-02 AM-241 36.9%	1.78E-02 AM-241 36.9%	9.28E-03 AM-241 36.9%	5.78E-03 AM-241 36.9%	1.76E-03 AM-241 36.9%
1.00E+03	3.72E+00 PU-240 42.7%	9.83E-01 PU-240 42.7%	3.56E-01 PU-240 42.7%	1.28E-01 PU-240 42.7%	3.19E-02 PU-240 42.7%	1.70E-02 PU-240 42.7%	1.08E-02 PU-240 42.7%	5.64E-03 PU-240 42.7%	3.51E-03 PU-240 42.7%	1.07E-03 PU-240 42.7%
2.00E+03	1.74E+00 PU-240 49.8%	4.60E-01 PU-240 49.8%	1.66E-01 PU-240 49.8%	5.96E-02 PU-240 49.8%	1.49E-02 PU-240 49.8%	7.96E-03 PU-240 49.8%	5.06E-03 PU-240 49.8%	2.64E-03 PU-240 49.8%	1.64E-03 PU-240 49.8%	5.00E-04 PU-240 49.8%
5.00E+03	2.93E-01 PU-239 50.0%	7.74E-02 PU-239 50.0%	2.81E-02 PU-239 50.0%	1.00E-02 PU-239 50.0%	2.51E-03 PU-239 50.0%	1.34E-03 PU-239 50.0%	8.52E-04 PU-239 50.0%	4.44E-04 PU-239 50.0%	2.77E-04 PU-239 50.0%	8.42E-05 PU-239 50.0%
1.00E+04	1.72E-02 PU-239 59.0%	4.55E-03 PU-239 59.0%	1.65E-03 PU-239 59.0%	5.90E-04 PU-239 59.0%	1.47E-04 PU-239 59.0%	7.87E-05 PU-239 59.0%	5.00E-05 PU-239 59.0%	2.61E-05 PU-239 59.0%	1.62E-05 PU-239 59.0%	4.95E-06 PU-239 59.0%
2.00E+04	6.53E-05 PU-239 74.6%	1.72E-05 PU-239 74.6%	6.25E-06 PU-239 74.6%	2.24E-06 PU-239 74.6%	5.60E-07 PU-239 74.6%	2.99E-07 PU-239 74.6%	1.90E-07 PU-239 74.6%	9.89E-08 PU-239 74.6%	6.16E-08 PU-239 74.6%	1.88E-08 PU-239 74.6%
5.00E+04	5.68E-12 PU-239 94.6%	1.50E-12 PU-239 94.6%	5.44E-13 PU-239 94.6%	1.95E-13 PU-239 94.6%	4.87E-14 PU-239 94.6%	2.60E-14 PU-239 94.6%	1.65E-14 PU-239 94.6%	8.61E-15 PU-239 94.6%	5.36E-15 PU-239 94.6%	1.63E-15 PU-239 94.6%
1.00E+05	1.47E-21 PU-239 92.7%	3.89E-24 PU-239 92.7%	1.41E-24 PU-239 92.7%	5.04E-25 PU-239 92.7%	1.26E-25 PU-239 92.7%	6.73E-26 PU-239 92.7%	4.28E-26 PU-239 92.7%	2.23E-26 PU-239 92.7%	1.39E-26 PU-239 92.7%	4.23E-27 PU-239 92.7%

Table B-4. Sample Problem. Extent of Contamination

4/08/81 07:55:30

LAND SURFACE RELEASE

EXTENT OF CONTAMINATION EVENT TIME : 1000.0 ORGAN:I

AREA (SQUARE METERS)

TIME (YEARS)	INCREMENTAL AREAS .5000-5.000	5.000-50.00	50.00-500.0	500.0-5000.	CUMULATIVE AREAS .5000 +	5.000 +	50.00 +	500.0 +	5000.+
1.00E+01	9.98E+04	5.70E+03	0.0	0.0	1.05E+05	5.70E+03	0.0	0.0	0.0
2.00E+01	9.87E+04	5.63E+03	0.0	0.0	1.04E+05	5.63E+03	0.0	0.0	0.0
5.00E+01	9.54E+04	5.43E+03	0.0	0.0	1.01E+05	5.43E+03	0.0	0.0	0.0
1.00E+02	8.99E+04	5.09E+03	0.0	0.0	9.50E+04	5.09E+03	0.0	0.0	0.0
2.00E+02	7.87E+04	4.40E+03	0.0	0.0	8.31E+04	4.40E+03	0.0	0.0	0.0
5.00E+02	4.51E+04	2.37E+03	0.0	0.0	4.75E+04	2.37E+03	0.0	0.0	0.0
1.00E+03	2.46E+04	0.0	0.0	0.0	2.46E+04	0.0	0.0	0.0	0.0
2.00E+03	7.56E+03	0.0	0.0	0.0	7.56E+03	0.0	0.0	0.0	0.0

THERE WERE NO CONTAMINATED AREAS FOR DOSES ABOVE 0.5REM AFTER 2.00E+03 YEARS

Table B-4. Sample Problem. Extent of Contamination

4/08/81 07:55:30 LAND SURFACE RELEASE

EXTENT OF CONTAMINATION EVENT TIME : 1000.0 ORGAN:1

AREA (SQUARE METERS)

TIME	INCREMENTAL AREAS					CUMULATIVE AREAS				
(YEARS)	.5000-5.000	5.000-50.00	50.00-500.0	500.0-5000.	.5000 +	5.000 +	50.00 +	500.0 +	5000.+
1.00E+01	9.98E+04	5.70E+03	0.0	0.0	1.05E+05	5.70E+03	0.0	0.0	0.0
2.00E+01	9.87E+04	5.63E+03	0.0	0.0	1.04E+05	5.63E+03	0.0	0.0	0.0
5.00E+01	9.54E+04	5.43E+03	0.0	0.0	1.01E+05	5.43E+03	0.0	0.0	0.0
1.00E+02	8.99E+04	5.09E+03	0.0	0.0	9.50E+04	5.09E+03	0.0	0.0	0.0
2.00E+02	7.87E+04	4.40E+03	0.0	0.0	8.31E+04	4.40E+03	0.0	0.0	0.0
5.00E+02	4.51E+04	2.37E+03	0.0	0.0	4.75E+04	2.37E+03	0.0	0.0	0.0
1.00E+03	2.46E+04	0.0	0.0	0.0	2.46E+04	0.0	0.0	0.0	0.0
2.00E+03	7.56E+03	0.0	0.0	0.0	7.56E+03	0.0	0.0	0.0	0.0

THERE WERE NO CONTAMINATED AREAS FOR DOSES ABOVE 0.5REM AFTER 2.00E+03 YEARS